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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM OF THE

WASHINGTON MEETING

AT THE

NATIONAL BUREAU OF STANDARDS

AND THE

GEORGE WASHINGTON UNIVERSITY

April 29–May 1, 1937

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APRIL 14, 1937 Vol. 12, No. 2

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

WASHINGTON MEETING, APRIL 29–MAY 1, 1937

THE 213th regular meeting of the American Physical Society will be held in Washington, D. C., on Thursday, Friday and Saturday, April 29, 30 and May 1, 1937. The Thursday and Friday sessions will be held at the National Bureau of Standards and the Saturday sessions at the George Washington University on 20th and 21st Streets between G and H Streets. The first session will be at 9:30 o'clock on Thursday morning.

There will be sessions in the East Building, the Chemistry Building and the Industrial Building of the National Bureau of Standards, and in Corcoran Hall, 21st Street between G and H Streets, of the George Washington University. The schedule of papers is given below.

Dinner. On Friday evening at 7:00 o'clock there will be a dinner for members and their friends at the Raleigh Hotel. The after-dinner speaker will be Mr. David Sarnoff, President of the Radio Corporation of America, whose subject will be "Science and Society." The price of the dinner will be $2.00. Tickets must be purchased at the registration desk at the National Bureau of Standards.

Luncheon. On Thursday and Friday luncheon will be served at 12:30 o'clock in the cafeteria in the Industrial Building at the National Bureau of Standards. Information regarding luncheon facilities for Saturday will be announced at the Saturday morning sessions.

Headquarters. Headquarters will be at the Raleigh Hotel, Pennsylvania Avenue at 12th Street. There will be a flat rate of $3.50 per day for single rooms with bath, $5.50 per day for double rooms with bath. Advance reservations are urged as hotels will be crowded. Please write directly to the hotel for accommodations.

Railroad Rates. Members should consult with their local ticket agents before purchasing tickets.

Summer Meeting at Denver. The summer meeting on the Pacific Coast will be held in affiliation with the American Association for the Advancement of Science at Denver, Colorado, June 21–25, 1937.

Summer Meeting at Madison, Wisconsin. The summer meeting in the east will be held at Madison, Wisconsin, June 22–23, 1937, by invitation from the Department of Physics of the University of Wisconsin.

Sigma Pi Sigma Luncheon. The luncheon of Sigma Pi Sigma members and guests, held annually in connection with the Washington meeting, will be at 12:45 on Saturday, May 1, at the Hay-Adams House, 16th and H Streets, N. W., just opposite the White House. Transportation will be provided, leaving shortly after the conclusion of the morning sessions. Members desiring to attend should leave their names at the information desk.

General Rules Relating to Papers

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

APR 16 1937

On December 28, 1936 the Society voted that:

No papers may be accepted for presentation at any meeting of the Society subsequent to the closing date stated in the printed call for that meeting.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program. (A paper presented by two or more authors is assigned to the first named author.)

All supplementary papers will be grouped according to subject matter and will be called for at their appropriate sessions only, these sessions to be designated on the program. The presiding officer may assign a reduced time to these papers or may in his discretion call for them to be read by title only.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts will be published in an early number of the *Physical Review*. Authors should send corrections to the Publications Manager, The American Institute of Physics Incorporated, 175 Fifth Avenue, New York, N. Y.

Other meetings for the current season are as follows:

214. June 21–25, 1937. Denver, Colorado. Pacific Coast Section in affiliation with the A.A.A.S.
215. June 22–23, 1937. Madison, Wisconsin.
216. November 26–27, 1937. Chicago, Illinois.
217. Pacific Coast Meeting. December 1937.
218. December 28–30, 1937. Annual Meeting. Indianapolis, Indiana.

W. L. SEVERINGHAUS, *Secretary*
Columbia University, New York, N. Y.

April 14, 1937.

CALENDAR

Thursday morning

9:30 o'clock: N B of S East Building: Papers 1–13. Pages 5–7.
9:30 o'clock: N B of S Industrial Building: Papers 14–25. Pages 8–10.
10:30 o'clock: N B of S South Building: Room 300: Council Meeting.

Thursday afternoon

2:00 o'clock: N B of S Industrial Building: Papers 26–35. Pages 10–12.
2:00 o'clock: N B of S East Building: Papers 36–45. Pages 12–14.
2:00 o'clock: N B of S Chemistry Building: Papers 46–56. Pages 15–17.

Friday morning

9:30 o'clock: N B of S Industrial Building: Papers 57–64. Pages 17–18.
9:30 o'clock: N B of S East Building: Papers 65–75. Pages 18–20.

Friday afternoon

2:00 o'clock: N B of S East Building: Papers 76–86. Pages 20–23.
2:00 o'clock: N B of S Chemistry Building: Papers 87–95. Pages 23–25.
2:00 o'clock: N B of S Industrial Building: Papers 96–108. Pages 25–27.

Friday evening

7:00 o'clock: Raleigh Hotel: Dinner: Speaker —Mr. David Sarnoff.

Saturday morning

9:30 o'clock: G W U Corcoran Hall: Room 29: Papers 109–119. Pages 27–29.
9:30 o'clock: G W U Corcoran Hall: Room 10: Papers 120–130. Pages 29–32.

Saturday afternoon

2:00 o'clock: G W U Corcoran Hall: Room 10: Papers 131–142. Pages 32–34.
2:00 o'clock: G W U Corcoran Hall: Room 29: Papers 143–156. Pages 35–37.

For Supplementary Papers 157–161 see Page 38.

PROGRAM

THURSDAY MORNING AT 9:30 O'CLOCK

National Bureau of Standards

East Building, Lecture Room

1. A Simplified Method for Indexing Debye-Scherrer-Hull Patterns. LUDO K. FREVEL, *The Dow Chemical Company, Midland, Michigan.* (*Introduced by J. D. Hanawalt.*)—The feasibility of finding a solution for the quadratic form of powder patterns has been limited to cubic crystal and to the simpler structures with tetragonal or hexagonal symmetry. Mathematical methods have been proposed to solve the case of three or more parameters; however, practical efforts to apply these devices have proved laborious and unsatisfactory. Yet in view of the simplicity and general applicability of the powder method, it is worthwhile to simplify the indexing of powder photographs of tetragonal and hexagonal substances and, moreover, to extend the simplification to orthorhombic and monoclinic crystals. In order to supplement the information gained by accurate spacing measurements, one records on a single film a direct temperature shift[1] of the diffraction pattern of a substance by taking two successive exposures, each at a constant temperature. An interval of 150°C or greater will generally suffice to produce easily measurable temperature shifts that can be related to the anisotropy of a crystalline substance. A systematic treatment of the various crystal systems has shown that the first four systems (cubic, tetragonal, hexagonal, and orthorhombic) can be indexed in a straightforward manner. Two cases of the monoclinic system: (1) $\partial\beta/\partial T=0$ and (2) $\alpha_b/2=(1/b)(\partial b/\partial T)>\alpha_a>\alpha_c>\cot\beta\cdot(\partial\beta/\partial T)$ can be solved without time-consuming mathematical calculations.

[1] L. K. Frevel, Rev. Sci. Inst. **6**, 214 (1935).

2. The Focusing of Electrons in an X-Ray Tube. N. C. BEESE, *Westinghouse Lamp Company, Bloomfield, N. J.*—A theory is proposed that accounts for the variations in the observed focal spot patterns on the anodes of x-ray tubes caused by changes in the geometry of the cathode structures. The focusing of electrons emitted by a helical filament within a focal cup can be explained qualitatively by elementary electrostatics. Data are presented to show the variations in size and energy distribution within the focal spots when changes are made in the dimensions of the focal cup mouth, throat, filament diameter and the mounting depth of the filament in the trough of the focal cup.

3. The Shape of the Density-Exposure Time Curve for X-Rays. F. R. HIRSH, JR., *Cornell University.*—Silberstein[1] has shown by a nuclear theory of photographic exposure that the probability of a quantum striking an active nucleus and reducing it to the latent image stage is $p_\lambda=(1-e^{-cE})$ where c is a constant and E is the "exposure"; this is of the same type of function as deduced by quantum theory. It may be shown that the slope of the density-exposure time curve is given by $D/t=k_1n_0(1-e^{-k_2n_0hp_\lambda t})$ where k_1 and k_2 are constants, and n_0 is the number of quanta of energy $h\nu$ incident on unit area of emulsion per second. It will be shown that for x-ray quanta of sufficient energy, p_λ, the probability function rises sharply to 1.0 as t increases. Thus only a small "foot" appears on density-exposure time curves for $\lambda\sim5.0$A; these curves appear to be straight lines passing through the origin.[2] For x-ray quanta of small energy, the probability function, p_λ, rises slowly to 1.0 as t increases, and a large "foot" should appear on the density-exposure time curve. A large "foot" is observed experimentally for curves taken with $\lambda\sim12.0$ to 14.0A.

[1] L. Silberstein, Phil. Mag. **5**, 464 (1928).
[2] F. R. Hirsh, Jr., J. O. S. A. **25**, 229 (1935).

4. Fourier Analysis of Liquid Methyl Alcohol. G. G. HARVEY, *Massachusetts Institute of Technology.*—The x-ray diffraction curve for liquid methyl alcohol at a temperature of about −75°C has been obtained with monochromatic Mo $K\alpha$ radiation out to $\sin\theta/\lambda=1.2$. At this temperature, which is about 22° above the freezing point, there is much greater detail in the diffraction curve than is observable at ordinary temperatures. Five diffraction rings are visible on the film whereas at higher temperatures it is difficult to distinguish a second one. It has consequently been possible to carry through a Fourier analysis and obtain a radial electron distribution function showing more distinct peaks than Zachariasen[1] was able to obtain from Stewart and Morrow's[2] data taken at room temperature. The results are, however, in substantial agreement with Zachariasen's conclusions with the addition that the present curve shows a very definite peak corresponding to oxygen-oxygen linkages, whereas at room temperature this peak is practically washed out. The distribution curve shows five well-defined peaks.

[1] Zachariasen, J. Chem. Phys. **3**, 158 (1935).
[2] Stewart and Morrow, Phys. Rev. **30**, 232 (1927).

5. The Crystal Structure of Potassium Tetrachloriodide. R. C. L. MOONEY, *Newcomb College, Tulane University.*—In connection with a study of the configuration of the polyhalogen anions of alkali metal salts, the crystal structure of a pentahalide, namely, potassium tetrachloriodide, has been determined by means of x-rays. The data, consisting of intensities observed photographically for more than two hundred planes, were obtained by the usual single crystal oscillation method. The crystal is monoclinic, and has the symmetry of $P2_1/n(C_{2h}^5)$. There are four molecules in a unit cell of dimensions: $a=12.89$A, $b=14.18$A, $c=4.17$A, Angle $\beta=95.7°$. The location of atomic positions involved the determination of eighteen parameters. Values for these have been found such that the calculated struc-

ture amplitudes of the proposed structure agree well with observations. No assumptions were made as to grouping or expected interatomic distances; the positions of the iodines were found from intensity considerations; the chlorine and potassium atoms were first approximately located from two dimensional Fourier analyses, and then fixed by intensity calculations. It is found that the halogens form a planar group, consisting of a central iodine surrounded by four chlorines at the corners of a square. The iodine to chlorine distances in a group are 2.3A and the chlorine to chlorine distances in different groups are more than 3.5A. There is a coordination sphere of eight chlorines about each potassium.

6. X-Ray Investigations of the Structure of Wood. W. I. CALDWELL AND K. LARK-HOROVITZ, *Purdue University.*—Preliminary experiments[1] have shown that wood, regardless of the appearance, exhibits x-ray diffraction patterns ranging from perfect fiber structure to almost completely homogenous diffraction rings. Extraction treatment did not change the cellulose pattern of the samples investigated. Even wood deteriorated under prolonged x-ray treatment yields the characteristic diffraction pattern. Systematic investigations have been carried out recently with wood samples graded according to origin, conditions of growth, mechanical properties and of known fibril angle.[2] Monochromatic Cu K radiation and a vacuum camera were used. Only cellulose patterns have been obtained. Lignin, investigated separately, gives a "liquid" pattern ($\sin\vartheta/\lambda$ corresponding to 0.045, 0.113, 0.222),[3] but no indication of it was found in any of the wood samples investigated so far. The results show that the presence or absence of fiber structure depends on the fibril angle: small fibril angle corresponds to fiber pattern, large fibril angles are accompanied by more homogenous pattern. These results are checked also by heat conductivity determination normal and parallel to grain (isotherm method).[4] Compression and spring wood have less pronounced fiber structure than summer wood.

[1] K. Lark-Horovitz, W. I. Caldwell, Phys. Rev. **15**, 749 (1934).
[2] We are indebted to Dr. A. Koehler and Mr. H. Y. Pillow, Forest Products Laboratory, Madison, Wisc., for selecting the samples and the information regarding mechanical and microscopical investigations.
[3] Experiments with Dr. E. P. Miller and Mr. G. C. Danielson.
[4] K. Lark-Horovitz, Nature **137**, 663 (1936).

7. X-Ray Diffraction Patterns from Crystalline Substances at Very High Hydrostatic Pressures. ROBERT B. JACOBS,* *Harvard University.* (*Introduced by W. L. Severinghaus.*)—An apparatus has been constructed which enables one to take Debye-Scherrer type x-ray spectrograms of substances under pure hydrostatic pressures as high as 4000 atmospheres. The usual comparatively soft x-rays useful for crystal work are employed (Cu K_α $\lambda=1.539$A). The x-ray beam enters the high pressure steel chamber through a small beryllium window; it there encounters the specimen and is diffracted to a photographic film which is bent inside the inner cylinder wall. The compressive medium is helium gas, which even at these pressures does not absorb the x-ray beam excessively. The quality of the diffraction lines obtained compares favorably with similar ones taken with a conventional camera at atmospheric pressure. Thus far the apparatus has been employed in the study of crystallographic changes which accompany polymorphic changes under pressure. KNO_3, $CsClO_4$, and AgI have been successfully studied in the pressure range 3000–4000 atmospheres. However, only the structure of the latter has been completely solved to date. At 3700 atmospheres, and at 25°C, it is found to have an NaCl type of cubic structure with unit edge 6.070 ± 0.010A with a corresponding density of 5.72.

* This work began while author was a National Research Fellow.

8. X-Ray Measurement of the Effect of Temperature on the Atomic Vibrations in Single Crystals of Zinc. G. E. M. JAUNCEY AND W. A. BRUCE, *Washington University.*—The investigations of the previous paper have been extended to temperatures of 100°, 200°, 298°, 370°, and 550°K for the scattering angle $\phi=30°$. Curves of $S\rho/\mu$ against the orientation angle ψ for these temperatures were obtained. In the front face method of measuring diffuse scattering it is very necessary to remove pits and other irregularities in the surfaces of the specimens. This was done by careful polishing, annealing, and etching. A theoretical investigation has shown how the ratio of the mean square displacement along the c-axis to that perpendicular to this axis may be obtained from the scattering values measured at different temperatures and different values of ψ for a given angle ϕ. The formula for this ratio does not contain the spectral distribution and is the same for the general radiation we used as for monochromatic radiation. Our results indicate this ratio to have a value between 2.7 and 3.1. This is greater than Zener's theoretical value of 1.80.

9. Variation of the Atomic Structure Factor of Nickel with Wave-Length in the Region of the Nickel K Absorption Limit. WILLIAM P. JESSE, *University of Chicago.*—With a vacuum ionization spectrometer comparison measurements have been made between the diffracted intensities from a briquet of powdered nickel and those from standard planes in briquets of powdered NaCl or LiF. Wave-lengths on both sides of the nickel K absorption limit (1.4839A) have been used with a range from 0.56A (Ag K_α) to 2.74A (Ti K_α). The values of the atomic structure factor for nickel for such wave-lengths were computed from known values of the structure factors for the standard substances. Corrections were made for very small variations in the standards with wave-length. If the theoretical dispersion curve of Hönl is fitted to the experimental curve at one point on the short wave-length side of the absorption edge, fairly good agreement between theory and experiment is obtained for points on the long wave-length side far removed from the absorption edge. A marked discrepancy is found closer to the absorption limit where the experimental curve rises more sharply and higher than the theory predicts. The experimental curve is in agreement with that determined for nickel by another method by Lameris and Prins.

10. Widths of L-Series Lines and of Energy Levels of Ag(47). LYMAN G. PARRATT, *Cornell University.*—The width of an x-ray line depends on the life-times of the

initial and final states of the emitting atom. With the concept of unsharp energy levels, the line width may be taken as the sum of the widths of the two energy levels involved. This simple sum relation may be checked experimentally if we assume (1) infinite spectrometric resolving power, (2) adequate resolution of a complex overlapping spectral contour into component lines, and (3) the perturbing effects of neighboring atoms to be negligible. Then the life-time of each of the two transition states is due to (1) what amounts to classical radiation damping and (2) radiationless transitions. Each of these two life-time contributions results in an absorption limit shape given by an arctangent curve (with certain assumptions)[1] and emission line shapes of the form $y=a/(1+(x/b)^2)$. These relations between line and level widths and line and level shapes have been experimentally studied for the *L*-series spectra, some 21 emission lines and the absorption limits, of Ag(47). The spectral (ionization) curves were recorded with a newly constructed two-crystal vacuum spectrometer.

[1] Richtmyer, Barnes and Ramberg, Phys. Rev. **46**, 843 (1934).

11. Geiger-Müller Counter Measurements of Reflected Mo $K\alpha$ X-Rays from Powdered Zinc. R. D. MILLER, *Washington University, St. Louis, Mo.*—Volz[1] has used the formula $n=n_0\exp(-n_0/2.718n_m)$, where n is the observed counting rate of the system, n_0 is the rate of production of pulses in the counter and n_m is the maximum possible counting rate. It was found that n_0, calculated from n and corrected for background count, varied as the inverse square of the distance from a gamma-ray source. Further, the absorption coefficient of Mo $K\alpha$ rays in aluminum was found to have the correct value when measured by means of this formula. Thus the formula was satisfactory. The absolute F values were obtained by comparison of the $(11\bar{2}2)$ reflection from zinc with the (420) reflection from KCl and the (220) reflection from MgO. An average of these gives $F(11\bar{2}2)=13.6$. Brindley, using Cu $K\alpha$ rays, obtains $F(11\bar{2}2)=12.0$. The difference is due to dispersion. The F values for other reflections very closely agree with those found by Brindley for Cu $K\alpha$ rays, when his values are corrected for dispersion. The very weak (0004) reflection, which was not obtained by Brindley, was found to have an F value of about 9.

[1] Volz, Zeits. f. Physik **93**, 540 (1935).

12. X-Ray and Optical Measurements of Multi-Molecular Films. CLIFFORD HOLLEY, *University of Chicago.*—Bragg diffraction and Michelson interference measurements of films of counted layers of barium stearate have been made. The films, kindly prepared by Dr. Blodgett, were of from 301 to 3000 molecular layers, counted as they were deposited upon the optically flat glass. The x-ray measurements showed equal thickness of the molecular layers in the various films within 0.08 percent, which is perhaps within experimental error. Two of the eight films used failed to show any diffraction. The interference measurements of the film thickness gave somewhat less consistent results, and indicated some expansion of the films with aging. Using the optically measured grating space of 48.40A, corresponding to a layer two molecules thick, the wave-length of the tungsten $M\alpha$ line is calculated to be 7.007A. This is to be compared with 6.969A from crystal measurements, or 6.984A as based on the ruled grating standard. Probable sources of error lie in the uncertainty of the refractive index of the stearate film for the x-rays, and possible phase changes when the light is reflected from the film and glass surfaces of the Michelson interferometer. The consistency of the results indicates that the method should become a valuable one for the determination of the absolute wave-length of x-rays.

13. Posnjak and Barth's Principle of "Variate Atom Equipoints," Superlattices and "Mixed Crystals." F. C. BLAKE, *Ohio State University.*—Seeking to understand, and if possible to legitimatize the idea of variate atom equipoints the writer has checked the results of the authors of the principle in the case of lithium ferrite and zinc stannate with material kindly supplied by them. In the case of the lithium ferrite, by quadrupling their lattice it is possible to obtain a perfect solution which is face-centered cubic in the fourth order. Since the first three orders for each of the components iron, lithium and oxygen go to zero the process of lattice enlargement can be generalized to any compound of the type ABX_2. The quadruple lattice with $a=16.564$ Angstroms contains 64 molecules of $Li_2Fe_2O_4$. Due to destructive interference superlattices are entirely absent. For the double lattice, $a=8.282$ Angstroms, superlattice lines should be present and it is evidently due to the interference process that they are removed in the larger lattice. Since the quadruple lattice contains more atoms than the present space-group theory allows its relation to this theory is discussed, as well as its relation to the theory of "mixed crystals." This paper is an attempt to elucidate the following sentence from Posnjak and Barth's[1] original paper on lithium ferrite, *viz.*, "Taking into consideration *not too small a portion of the crystal*, an equal number of points is occupied by iron and by lithium." Search should be made for other generalized simple cubic and body-centered cubic lattices as well as for this generalized face-centered cubic lattice.

[1] Posnjak and Barth, Phys. Rev. **38**, 2237 (1931).

THURSDAY MORNING AT 9:30 O'CLOCK

National Bureau of Standards

Industrial Building, Room 301

14. The Interpretation of the Red Shift of Extra-Galactic Nebulae. ARTHUR HAAS, *University of Notre Dame.*—The work required for an expansion of the system of nebulae is $q=\frac{4}{3}\pi fR^3\rho\alpha$ in erg/g/sec. (R, radius of system; f, gravitational constant; ρ, mean mass density; $\alpha=1.8\times10^{-17}$ sec.$^{-1}$ or reciprocal of 1700 million years). Hence $q=7\times10^{39}\rho y^2$, where $y=R/R^*$ and R^* ($=5\times10^{26}$ cm) is the largest observed nebular distance. Inserting Hubble's recent value ($\rho=10^{-26}$), we find $q\approx7000y^2$. Since 1 gram cannot produce more energy than 9×10^{20} erg, and the production must last for 1.7×10^9 years, we find that $7000y^2<9\times10^{20}\times\alpha$, or that $y<2$; even for $\rho=10^{-28}$, we find $y<20$. The expansion idea is therefore compatible with the empirical gravitational law only if we assume both that the system of nebulae does not extend much farther than 500 million light years, and that matter is subject to a process of dissolution not much slower than the expansion itself. To avoid the hypothesis of a dissolution, we must either modify Newton's gravitational law or interpret the red shift as a continual energy loss of the photons. In any case we find, irrespective of the value of ρ, agreement between the energy production by the nebulae and the continual diminution of radiant energy traveling in space, since both quantities amount to about 7×10^{-32} erg/cc/sec.

15. Dynamical Effects of Radiation in the Solar System. H. P. ROBERTSON, *Princeton University.*—At the instance of H. N. Russell, the author has reexamined from the standpoint of the theory of relativity the problem, treated by J. H. Poynting and by J. Larmor, of the motion of a small particle in the gravitational field of the sun, on the assumption that the radiation it receives from the sun is reemitted isotropically and at the same rate R. It is found that, in the classical approximation, such a particle suffers a retarding force Rv/c^2 (three times that found by Poynting and one-half of that found by Larmor), where v is its velocity relative to an inertial frame in which the sun is at rest, and c is the velocity of light. The resulting loss of angular momentum causes a secular decrease in the mean distance of the particle from the sun, which for particles of radius up to a few centimeters has the effect of drawing the particles into the sun in astronomically significant times, as predicted by Poynting.

16. Interatomic Distances of the Alkali Halides. L. R. MAXWELL, S. B. HENDRICKS AND V. M. MOSLEY, *Bureau of Chemistry and Soils.*—A determination of the interatomic distances of the alkali halide gas molecules has been made by the electron diffraction method. Heating the salts to a temperature of approximately 1200°C provided a molecular beam of sufficient density to give electron diffraction photographs. Since the molecules were diatomic the nuclear distances were easily obtained from visual measurements of the interference maxima. Data obtained from I_2 and Cl_2 served as a method for calibration of the visual measurements since the internuclear distances for these molecules are well known from band spectra. The interatomic distances for the sodium, potassium and rubidium halides were found to be consistently smaller than the corresponding known distances in the crystal lattice. For the case of the caesium halides the distances obtained were still smaller than the separations found in the crystals. The following table gives the distances measured.

	INTERATOMIC DISTANCE (A)		INTERATOMIC DISTANCE (A)
NaCl	2.51±0.03*	RbCl	2.89±0.01
NaBr	2.64±0.01	RbBr	3.06±0.02
NaI	2.90±0.02	RbI	3.26±0.02
KCl	2.79±0.02	CsCl	3.06±0.03
KBr	2.94±0.03	CsBr	3.14±0.03
KI	3.23±0.04	CsI	3.41±0.03

* Variation given represents the average deviation obtained.

17. Λ-Type Doubling in the $^3\Pi$ State of OH^+. C. N. CHALLACOMBE, *University of Illinois.*—A method has been recently developed by Hebb for the calculation of the Λ-type doubling in the $^3\Pi$ states of diatomic molecules intermediate between Hund's cases a and b. Hebb has applied the method to the $^3\Pi$ state ($v'=6$) of the first positive bands of nitrogen in which the ratio of the molecular constants $A/B=27.9$, and Gilbert has applied the method to the $^3\Pi$ state of PH in which $A/B=-14.4$. It appeared worthwhile to apply Hebb's method to a state with a smaller value of A/B, which would therefore lie more definitely in the transition region, and for which the adequacy of the theory to represent the $^3\Pi$ transition levels could be more rigorously tested. The $^3\Pi$ state of OH^+ ($v'=0$) for which $A/B=-6.19$ is quite suitable for such a calculation. The Λ-type doubling in this state is considerably larger than it is in the two states previously investigated and the experimental data available for comparison with the calculated values are quite complete. The final equation from which the Λ-type doubling is computed contains three adjustable constants. With the values $C_0=-7.85$ cm^{-1}, $C_1=-0.190$ cm^{-1}, $C_2=0.0218$ cm^{-1}, a rather good agreement with the experimental data of Loomis and Brandt was obtained.

18. The Energy Levels of the Asymmetrical Rotator and the Correspondence Principle. ENOS E. WITMER, *University of Pennsylvania.*—If a, b, and c are the reciprocals of the principal moments of inertia of an asymmetrical rotator, then the energy according to quantum mechanics[1] may be written

$$E=(h^2/8\pi^2)J(J+1)\{a+(c-a)\tau(s;\,n,\,J)\}, \qquad (1)$$

where $$s=(b-c)/(a-c).$$

If $a\geqslant b\geqslant c$, then $0\leqslant s\leqslant1$ and $0\leqslant\tau(s;\,n,\,J)\leqslant1$. J and n are the quantum numbers used by Kramers and Ittmann.

According to the old quantum theory

$$E=\frac{h^2}{8\pi^2}J^2\left\{a+(c-a)\tau_c\left(s;\frac{n_2}{J}\right)\right\}, \tag{2}$$

where n_2 is the second quantum number. In the case when the energy levels form close doublets as measured by the difference in $\tau(s; n, J)$, it is now found that

$$\tau(s; n, J)\cong\tau_c\left(s;\frac{J+n+(1)}{2[J(J+1)]^{\frac{1}{2}}}\right) \tag{3}$$

for motions of one class. The (1) in $J+n+(1)$ is used only when $(J+n)$ is odd. Formula (3) holds to a very high degree of approximation even when J is as small as 3. This means that *in the case of close doublets the classical quantum formula gives very accurate results, if J is replaced by $[J(J+1)]^{\frac{1}{2}}$ and n_2 by $\frac{1}{2}[J+n+(1)]$ for motions of one class.* For those of the other class a similar formula holds.

[1] E. E. Witmer, Phys. Rev. **47**, 340 (1935).

19. A Theoretical Test of the Franck-Condon Approximation. HUBERT M. JAMES AND ALBERT SPRAGUE COOLIDGE, *Purdue University and Harvard University.*—It has been shown[1] that there is a marked disagreement between observed intensity distributions in the continuous spectrum of H_2 and the results of a theoretical treatment involving the Franck-Condon principle as the only essential assumption. To check the conclusion that this is due to the failure of the Franck-Condon approximation we have computed the electric dipole moment between the electronic states involved ($1s\sigma 2s\sigma\ {}^3\Sigma_g$ and $1s\sigma 2p\sigma\ {}^3\Sigma_u$). This required the determination, by variational methods, of potential curves and electronic wave functions of these states for a considerable range of nuclear separation. It was found that the ${}^3\Sigma_u$ repulsive curve is given to only a poor approximation by the Heitler-London method, even for a nuclear separation of $2.9a_H$. The square of the dipole moment between the states, variation of which measures the error of the Franck-Condon approximation, was found to change by a factor of 10 within the relevant range of nuclear separation in the most favorable case; for ordinary types of excitation a still greater variation comes into account. The correction to the previous computations is of the right sign and order of magnitude. A complete theoretical treatment of this spectrum is under way.

[1] A. S. Coolidge, H. M. James and R. D. Present, J. Chem. Phys. **4**, 193 (1936).

20. On Electron Excitation in Crystals. GREGORY H. WANNIER, *Princeton University. (Introduced by J. C. Slater.)*—If we assume the wave function corresponding to the excitation of an electron in a crystal to be a linear combination of excitation waves

$$\psi=\sum_{\beta}U_\alpha(\boldsymbol{\beta})\cdot E(\mathbf{K}_\alpha, \mathbf{R}_\beta),$$

then $U_\alpha(\boldsymbol{\beta})$ has not the values which correspond to the Bloch picture. Its true value may be found from a study of the energy matrix, because the matrix equation can be approximated by a simple type of differential equation. Most forces which act on the electron or its "hole" have the periodicity of the lattice. Hence their Hamiltonian is a purely differential operator P acting on $U_\alpha(\boldsymbol{\beta})$. One finds

$$P\cdot U(\boldsymbol{\beta})=[e^{-\frac{1}{2}i\mathbf{K}_\alpha\cdot\boldsymbol{\beta}}W_{\text{exc}}(-i\partial/\partial\boldsymbol{\beta})e^{+\frac{1}{2}i\mathbf{K}_\alpha\cdot\boldsymbol{\beta}} - e^{+\frac{1}{2}i\mathbf{K}_\alpha\cdot\boldsymbol{\beta}}W_{\text{ground}}(-i\partial/\partial\boldsymbol{\beta})e^{-\frac{1}{2}i\mathbf{K}_\alpha\cdot\boldsymbol{\beta}}]U(\boldsymbol{\beta}),$$

where the $W_\nu(\mathbf{k})$ are the relations between the energy W and the wave vector $\mathbf{k}$ in the two Bloch bands. The largest nonperiodic terms in the Hamiltonian arise from the Coulomb attraction between the electron and its hole. The nondiagonal terms are rather small and the diagonal ones are simply $-e^2/|\mathbf{R}_\beta|$. The operators W are symbolic power series, whose first significant term is const$\cdot\nabla^2$. The corresponding differential equation can be solved explicitly. In particular for the optically accessible levels, $\mathbf{K}_\alpha=\mathbf{O}$, it reduces to the Schrödinger equation for the hydrogen atom. We find therefore below the excited energy band a set of discrete states which carry no current. Their energies are approximately

$$E_n=-E_1/n^2,$$

where E_1 is a constant generally smaller than for hydrogen. These states must form the basis for the electrically inactive absorption of many crystals in the near ultraviolet.

21. The Application of the Virial Theorem to Approximate Eigenfunctions. JOSEPH O. HIRSCHFELDER AND JOHN F. KINCAID, *Princeton University.*—The virial theorem, $\bar{V}=-2\bar{T}$, is automatically satisfied if into any approximate atomic or molecular eigenfunction a scale factor, s, is introduced and varied to give the lowest energy. Here $\bar{V}$ and $\bar{T}$ are the averaged potential and kinetic energies of the system neglecting the motions of the nuclei from their mean positions. Since the scale factor multiplies every distance in the eigenfunctions by s, it follows from dimensional considerations that: $\bar{V}_s=s\bar{V}_{s=1}$ and $\bar{T}_s=s^2\bar{T}_{s=1}$. The total energy, $E=\bar{V}_s+\bar{T}_s$, is least when $s=-\frac{1}{2}\bar{V}_{s=1}/\bar{T}_{s=1}$ and $E_{(\min)}=\frac{1}{2}\bar{V}_s=-\bar{T}_s=-\frac{1}{4}\times\bar{V}^2_{s=1}/\bar{T}_{s=1}$. The Heitler-London eigenfunction for H_2 gives $\frac{1}{2}\bar{V}=-26.49$ ev, $-\bar{T}=-22.79$ ev, and $E=-30.20$ ev. The introduction of the scale factor, $s=1.166$, converts this to the Wang function and gives: $\frac{1}{2}\bar{V}_s=-\bar{T}_s=E_s=-30.83$ ev. The improvement in the total energy is only 0.63 ev while the potential energy changes 8.67 ev and the kinetic energy 8.04 ev. The Coolidge and James function for H_2 nearly satisfies the virial theorem since $\frac{1}{2}\bar{V}=-31.680$ ev, $-\bar{T}=-31.588$ ev, $E=-31.772$ ev. Introducing the scale factor $s=1.0029$ we obtain: $+\frac{1}{2}\bar{V}_s=-\bar{T}_s=E_s=-31.772$ ev. Physical properties proportional to the nth power of some distance are improved by the factor $s^{-n}=(\bar{V}/2\bar{T})^{-n}$ by introducing the scale factor and satisfying the virial theorem.

22. Van der Waals Forces between Helium Atoms. CHESTER H. PAGE, *Yale University.*—The Slater-Kirkwood variation method of calculating van der Waals energy has been extended to include the dipole-quadrupole interaction. The variation function used is $\psi=\psi_0(1+\lambda v e^{\beta R})$, where ψ_0 is the wave function of a normal helium atom, R the sum of the distances of the electrons from their proper nuclei, λ and β variation parameters, and v the interaction perturbation, taking only the dipole-dipole and dipole-quadrupole terms in the Taylor expansion of the classical mutual potential of

the two atoms. Using $\psi_0=(r_1r_2)^{n-1}e^{-(z'/n)(r_1+r_2)}$, we find at a separation of 2.9A, that for $n=1$, $z'=1.6875$, the dipole-quadrupole energy is 13 percent of the dipole-dipole energy, as against the 26 percent found by Margenau, by an approximate second order perturbation method. For $n=0.75$, $z'=1$, we obtain correspondingly 26 percent against Margenau's estimated 32 percent. The method is being further extended, by using the complete perturbation function in closed form, instead of the first terms of the series expansion.

23. The Distortion of a Closed Shell due to Crystallic Fields. VIVIAN A. JOHNSON AND L. W. NORDHEIM, *Purdue University.*—The intensities of the electron diffraction pattern in zinc oxide show systematic anomalies as compared with the corresponding intensities of the x-ray diffraction pattern.[1] For explanation of these anomalies selective absorption, anisotropic heat motion or dynamical reflection has been suggested. The observed intensities have been formally accounted for by assuming a polarization of the *M* shell of the Zn atoms.[1] Such a distortion might be due to the electrostatic fields arising from a partly ionic character of the lattice and its deviation from perfect tetrahedral symmetry. To test this hypothesis we have worked out the changes in charge distribution of the *M* shell in zinc due to fields of linear or tetrahedral symmetry. Following a suggestion of Bethe the distorted wave functions have been obtained by numerical integration. The Thomas-Fermi potential was used to obtain the unperturbed wave functions. The possible magnitude of the internal electrostatic field has been estimated by computing the corresponding terms of lattice potentials for an ionic lattice. The distortion calculated under these assumptions is too small by a factor of about 1/30 to account alone for the observed anomalies, and some of the other effects, mentioned above, will have to be considered.

[1] K. Lark-Horovitz, H. J. Yearian, Phys. Rev. **42**, 905 (1932); H. J. Yearian, Phys. Rev. **48**, 631 (1935).

24. On the Electronic Constitution of Diamond. DOUGLAS H. EWING, *The University of Rochester.*—A self-consistent field for diamond is being constructed, following the method of Wigner and Seitz, and some preliminary results are described. This problem has already been attacked by Kimball,[1] but no anisotropy of charge density was displayed in his approximation. The approximation used in the present case employs more terms in the expansion of wave functions in terms of surface harmonics and leads to anisotropy. Plots of the charge distribution in different crystallographic directions are shown and the degree of concentration of charge in the classical bond direction discussed.

[1] Kimball, J. Chem. Phys. **3**, 560 (1935).

25. The Lattice Energy of Solid CO_2. H. SPONER AND M. BRUCH-WILLSTÄTTER, *Duke University.*—Carbon dioxide crystallizes at very low temperatures in a cubic face-centered lattice. For the calculation of its energy a two-center model has been used for the single linear and long shaped CO_2 molecules by assuming that the O-atoms contribute mostly to the polarizability; furthermore that the polarizability of the two centers should not be located in the nucleus of the O-atoms but should be somewhat shifted toward the C-atom. The simple London theory of van der Waals forces is applied to this model. Different assumptions about the location of the polarizabilities have been discussed and values of 5–6.6 kcal./mole, respectively, are obtained for the sublimation heat of solid CO_2. The experimental value is 6.44 kcal./mole. For a more accurate calculation the second approximation of van der Waals forces (Margenau's formula), electrostatic forces due to compensated dipoles in the CO_2 molecules and the repulsive forces have been considered. The charge distribution seems to be better represented with a model of point charges with definite distances than with the ordinary picture of short dipoles. The repulsive forces could be treated only in a rough way. Discussion shows, however, that one can account theoretically for the observed value.

THURSDAY AFTERNOON AT 2:00 O'CLOCK

National Bureau of Standards

Industrial Building, Room 301

26. Analytic Wave Functions for Nuclear and Atomic Collision Problems. PHILIP M. MORSE, *Massachusetts Institute of Technology.*—The wave function $\sin(kr+\delta)-\exp(-\alpha r)\sin(\delta)\cos(kr)$ is a good approximation to the $l=0$ continuous wave function for a centrally symmetric field, as long as the phase angle δ is less than 180 degrees. The parameters α and δ can be determined by a variational method, minimizing the average value of $(H-k^2)^2$. However, it is found that the ratio between α and the scale factor for any chosen potential field can be fixed, and the phase angle δ can be obtained for different values of k by setting the average value of $(H-k^2)$ equal to zero, a much simpler process. Such a procedure, used with the two fields $D\exp(-2\beta r)-2D\exp(-\beta r)$ and $(Z/r)\exp(-\beta r)$, gave values of δ within a few degrees of the exact values, over the range of k from zero to two. The above wave function is useful in calculations of inelastic and exchange collision cross sections, giving much more accurate results than the Born approximation, which assumes δ to be zero. The function can also be modified to include approximately the polarization of the target atom.

27. Low Energy Collision of Neutron and Deuteron. L. I. SCHIFF, *Massachusetts Institute of Technology.*—The elastic scattering of neutrons by deuterons is considered theoretically for energies so small that only the $l=0$ part of the incident neutron beam is different from the corresponding part of a plane wave. An iteration method is employed using the same mixed Majorana-Heisenberg interaction between all pairs of particles. For the zero approximation wave-function which goes into the iteration integral, a form is used which has one variable parameter, the phase shift at infinity, which is fitted to an average deuteron field. This form takes into account the distortion of the $l=0$ part of the neutron wave near the deuteron, and gives the correct order of magnitude for the low energy elastic scattering cross section. The same form also gives very close to the correct $l=0$ phase shift for the neutron-proton collision over a wide range of energies. The iteration process serves to improve on this by taking account of the exchange nature of the forces and of ejection of the originally bound neutron with capture of the incident neutron. The same approximate wave-function can be used to compute the magnetic dipole capture cross section at low energies.

28. Variational Calculations on the Nuclear Three and Four Body Problem. HENRY MARGENAU AND DANA T. WARREN, *Yale University.*—The present method has the following advantages: (1) It can be used with potentials of the form Ae^{-r^2/a^2}, for which the constants are best known, (2) It is applicable to the four body problem, (3) The functions used form a complete set, and the results must converge to the true value. The method consists in expressing the relative coordinates of the particles in terms of the minimum number of independent coordinates. Simple harmonic oscillator functions in these coordinates are added systematically, the lowest one giving the exponential function of Feenberg and Bethe and Bacher. Thus completeness is assured, and the orthogonality of the functions limits the energy in the secular determinant to the diagonal elements, permitting very simple solution by successive approximations. This method has been thoroughly studied in the case of the deuteron. The constants $A=35.60$ MV, $a=2.25\times10^{-13}$ cm, $g=0.20$ are adopted. The use of ten functions for H^3 gives 7.21 MV for the binding energy (experimental value 8.3 MV).

29. Perturbation Theory of Light Nuclei: O^{16}. W. J. KROEGER AND D. R. INGLIS, *University of Pittsburgh.*—The limitations of the perturbation method of calculating nuclear properties, starting with independent particles in a central field,[1] come into evidence in a calculation of the binding energy of O^{16}. It is found that the third-order contributions of the doubly excited states are about as great as their second-order contributions. The convergence is thus not rapid enough to make a reasonably complete calculation practicable, contrary to the case[1] in Li^6. This difference appears in the calculation most prominently in factors of the type $H_{22}'-H_{00}'$, which occur in the third-order energy and increase in magnitude with increasing atomic number.

[1] Inglis, Phys. Rev., April 1, 1937; and first-order calculations by Heisenberg, Zeits. f. Physik **96**, 473 (1935); Bethe and Bacher, Rev. Mod. Phys. **8**, 82 (1936); Feenberg and Wigner, Phys. Rev. **51**, 95 (1937); Rose and Bethe, Phys. Rev. **51**, 205 (1937).

30. Depolarization by Neutron Proton Scattering. JULIAN SCHWINGER AND I. I. RABI, *Columbia University.*—The production of neutrons which are preferentially polarized in some given direction has been demonstrated by recent experiments. We wish to point out that these neutrons may be used to study spin dependent nuclear forces. If a stream of neutrons of average polarization $\boldsymbol{\sigma}_n$ is scattered by hydrogen it can be shown that the resultant polarization of the scattered neutrons after a single collision is given by

$$\boldsymbol{\sigma}_n'=\left(1-\frac{(a_1-a_0)^2}{3a_1^2+a_0^2}\right)\boldsymbol{\sigma}_n.$$

The quantities a_1 and a_0 are connected with the phase shifts of the triplet and singlet scattered waves, respectively, by

$$a_{1,0}=\sin\delta_{1,0}/k.$$

The ratio a_0/a_1 depends upon the range of the nuclear forces. The sign of this ratio is positive if the singlet state is real, negative if virtual. It is apparent that a measure of the depolarization gives important information about the nuclear forces. For example, an assumed range of $2\cdot10^{-13}$ cm gives $a_0/a_1=\pm3.41$ for slow neutrons. The upper sign gives $\boldsymbol{\sigma}_n'=0.60\boldsymbol{\sigma}_n$ whereas the lower sign yields $\boldsymbol{\sigma}_n'=-0.33\boldsymbol{\sigma}_n$.

31. Fluctuations in Radiative Energy Loss and Range of Fast Particles. W. H. FURRY, *Harvard University.*—If, as is indicated by recent experiments of Anderson and Neddermeyer, the Bethe-Heitler formula gives a correct description of the radiative losses of high energy electrons, then the fluctuations in these losses should be very great. For the case of absorption in lead, the ionization loss can reasonably be treated as simply proportional to the thickness, and applied as a correction at the end of the calculation. When this is done, the partial differentio-integral equation for the distribution in energy as a function of the thickness traversed can be solved without serious modification. The distribution curves are given with remarkably high accuracy by the saddle-point method. Results so far obtained are insufficient for the determination of mean ranges; it is already evident that the *median* ranges for various energies are markedly less than the "ranges" calculated from a simple differential equation, $dE/dx=-kE-\beta$, in which the mean radiative loss is used, but that the fluctuations are extremely large. Complete sets of curves for both energy loss and range will be shown.

32. Disintegrations of Very Heavy Nuclei by Deuterons. H. A. BETHE, *Cornell University.*—When deuterons interact with very heavy nuclei ($A\approx200$), the most probable primary processes are the emission of a neutron and a proton. The latter process follows the Oppenheimer-

Phillips mechanism, the former the ordinary Bohr mechanism. The emission of protons or α-particles in the ordinary mechanism is very improbable because the number of possible states of the final nucleus is smaller than for neutron emission by a factor of about 100,000. Neutron emission and Oppenheimer-Phillips process should be about equally probable. The emitted neutron will have a kinetic energy of about 1 MV (nuclear temperature), the proton about the same as the incident deuteron. The residual nucleus is therefore left with an excitation energy of about 7 and 4 MV, respectively. Since even the ground state of heavy nuclei is energetically unstable against α-emission with about 4 MV, the residual nucleus will be able to emit α-particles. This process should be somewhat more probable than γ-emission for 7 MV excitation, somewhat less for 4 MV. Therefore the nuclei formed in the *dn*-process will ordinarily, those formed in the *dp*-process occasionally, disintegrate further with α-emission. The most probable processes with heavy nuclei are thus (approximately in order of their probability)

$$Z^A+H^2=Z^{A+1}+H^1, \quad \text{I}$$
$$Z^A+H^2=(Z-1)^{A-3}+He^4+n^1, \quad \text{II}$$
$$Z^A+H^2=(Z-2)^{A-3}+He^4+H^1, \quad \text{III}$$
$$Z^A+H^2=(Z+1)^{A+1}+n^1. \quad \text{IV}$$

Experimental evidence for process III was obtained by Cork and Thornton, for II by Cork and Lawrence; IV has not yet been observed.

33. The Evaporation Model of Nuclear Disintegrations. E. J. KONOPINSKI* AND H. A. BETHE, *Cornell University.*—The evaporation picture of nuclear disintegrations makes it possible to express the disintegration probability or "level width" of a compound nucleus in terms of its formation probability. This contains, besides certain known factors, a quantity ξ which expresses the "sticking probability" of a particle to a nucleus it strikes. ξ is expected to be unity for high excitations; for low excitations, its magnitude can be estimated from neutron experiments which gives the ratio of level width to spacing, Γ_n/D. The values of ξ thus obtained range from 0.01 to 0.1. A more detailed theoretical discussion of the evaporation will be made in terms of the interference of elastic waves in the nuclear liquid. When the expression for the average Γ_n/D in terms of ξ is introduced into the dispersion formula, for the probability of nuclear disintegrations, the result is gratifyingly simple: $\sigma=\pi R^2\xi(\Gamma_{BQ}/\Gamma)$. Thus the cross section for the disintegration of a compound nucleus into parts *B* and *Q* is given by the product of its formation cross section $\pi R^2\xi$ and by the probability of the disintegration mode *BQ*, in competition with the total possibilities, Γ.

* National Research Fellow.

34. The Magnetic Moment of the Proton. I. ESTERMANN, O. C. SIMPSON, AND O. STERN, *Carnegie Institute of Technology.*—The magnetic deflections of H_2 and HD molecules have been measured at room temperature and at 90°K. The deflection $S_\alpha{}^p(90°\text{K})$, i.e., the deflection of a molecule having the most probable velocity α corresponding to 90°K and the magnetic moment of one proton, is calculated from these measurements. The results are given in the table.

	T	$S_\alpha{}^p(90°\text{K})$
H_2	90°	7.52 mm/100
HD	90°	7.50 mm/100
H_2	291°	7.52$_5$ mm/100
HD	291°	7.82 mm/100

Each value of $S_\alpha{}^p$ represents the average of a large series of measurements agreeing within a few percent, except for the value for HD at 291°K which we did not attempt to measure with the same accuracy on account of the small deflection and the large number of rotational quantum states. The error in the mean value $\overline{S_\alpha{}^p}(90°\text{K})=7.52$ mm/100 should be appreciably less than one percent. With the dimensions of our apparatus and a preliminary value of the inhomogeneity of the magnetic field, the above value of $S_\alpha{}^p$ gives a proton moment of about 2.6 nuclear magnetons. Our first measurements** gave 2.5±10 percent.

* R. Frisch and O. Stern, Zeits. f. Physik **85**, 4 (1933).
** I. Estermann and O. Stern, Zeits. f. Physik **85**, 17 (1933).

35. A New Method for the Measurement of the Bohr Magneton. O. STERN, *Carnegie Institute of Technology.*—The free fall of molecules could be measured by producing a long horizontal beam. In the case of magnetic atoms the force of gravity can be compensated for a part of the atoms by an inhomogeneous magnetic field. This field may be produced by the current I in a wire parallel to the beam and situated below it in the distance r. Exact cancellation of the two forces takes place if $mg=\mu_0(dH/dr)_0=\mu_0(2I_0/r^2)$. If $I<I_0$ all atoms are deflected downward, if $I>I_0$ a part of the atoms is deflected upward. Thus I_0 can be determined by placing the detector above the "straight" beam and increasing I until we receive atoms. In this way we can measure μ_0, that is, $N\mu_0=(Mg/2I_0)r^2$. The magnetic splitting in many beams due to the nuclear moment does not matter because the most strongly deflected atoms have always one Bohr magneton.

THURSDAY AFTERNOON AT 2:00 O'CLOCK

National Bureau of Standards

East Building, Lecture Room

36. The Reflection of Radio Waves in the Troposphere. R. C. COLWELL AND A. W. FRIEND, *West Virginia University.*—For the last year, daily measurements have been made of the *C* region in the troposphere. The height of the region and the polarization of radio waves reflected from it were recorded. At the same time observations were made upon the signal strength of nearby broadcasting stations, and the skip distance on short wave stations. These were

correlated with the barometric pressure and other weather conditions. As a general rule, when the barometer is high, the *C* region is low and *vice versa*. The change in height affects the skip distance.

37. Variations of Cosmic Rays with Latitude on the Pacific Ocean. A. H. COMPTON, *University of Chicago* AND R. N. TURNER, *Canadian-Australasian Steamship Co.*—A series of 12 continuous measurements of the cosmic-ray ionization have been completed between Vancouver, Canada and Sydney, Australia, via Honolulu, Suva, and Auckland, with a Carnegie Model C meter. The repeated measurements give a higher precision than heretofore attainable in such work, and afford a basis for estimating the probable errors involved. The shape of the latitude effect curve is unsymmetrical with respect to the equator, and the latitudes at which the breaks in the curve occur differ in the two hemispheres.

38. The Influence of the Earth's Magnetic Field on Cosmic-Ray Intensities up to the Top of the Atmosphere. I. S. BOWEN, R. A. MILLIKAN AND H. V. NEHER, *California Institute of Technology*.—Measurement on cosmic-ray intensities like those made in July 1936 at San Antonio, Texas, and already published,[1] have now been made with equal accuracy in Madras, India. A comparison of the two resulting curves and that earlier obtained in the Fordney-Settle flight makes it possible for the first time to determine experimentally the complete law of absorption of electrons going through the atmosphere in two different ranges of energy, namely, from 2.5×10^3 Mev to 6×10^3 Mev, and from 6×10^3 Mev to 12×10^3 Mev. A law not greatly different from the Bethe-Heitler law as extended by Carlson and Oppenheimer[2] is found to reproduce reasonably well the observed findings.

[1] Phys. Rev. **50**, 992–998 (1936).
[2] Phys. Rev. **51**, 22 (1937).

39. On Diurnal Variation in Cosmic-Ray Intensity. S. E. FORBUSH, *Department of Terrestrial Magnetism, Carnegie Institution of Washington*.—Continuous cosmic-ray intensity data for some 360 complete days as recorded at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey are subjected to statistical analysis. Cheltenham is one of the world net of cosmic-ray recording stations established by the Carnegie Institution of Washington. The precision cosmic-ray meter used is after the design for the Institution by Compton, Wollan, and Bennett. The results indicate that the real barometric coefficient does not change from hour to hour or from month to month. The barometric coefficient obtained at this station is in good agreement with that indicated by certain altitude-intensity curves. The effect of external air-temperature upon the intensity, reported by some observers, has been examined by two independent statistical methods, both of which indicate that no such effect exists at Cheltenham. Finally, the data have been subjected to modern statistical methods which provide an objective measure for the probability that the observed diurnal-variation is real. The results indicate, for the period covered by this analysis, a physically significant 24-hour wave in apparent cosmic-ray intensity, with an amplitude of 0.17 percent of the total intensity, having its maximum at about 11^h, 75° west meridian mean time.

40. Penetrating Corpuscular Component of the Cosmic Radiation. J. C. STREET AND E. C. STEVENSON, *Harvard University*.—The confirmation of the validity of the Heitler theory of radiation and pair formation both by energy loss measurements[1] and by the nature of shower formation[2, 3] leaves no explanation for the penetrating corpuscular rays except to assume that they are protons. However, the evidence against protons is strong.[4] To investigate the penetrating rays a vertical column was set up as follows: a counter, 10 cm Pb, a second counter, a cloud chamber in a magnetic field, a third and fourth counter, 3 cm Pb, and finally a cloud chamber containing 3 separated lead plates 1 cm thick. The counter telescope selected particles directed toward the visible region of the lower chamber where their absorption and shower production was observed. The distribution of the particles with respect to range and $H\rho$ values was as follows:

$H\rho\times10^{-6}$	% OF TOTAL TRACKS	FRACTION WITH RANGE >3 cm Pb	FRACTION WITH RANGE >6 cm Pb
5	49	1	1
2.5 to 5	19	.9	.7
1.5 to 2.5	23	.9	.7
0.7 to 2.5	9	.7	.3

Only a single shower has been observed in 500 traversals of 1 cm of lead. The ionization density of protons with $H\rho<2.5\times10^6$ distinguishes them, and two were observed. From the data in the table it is evident that the penetrating particles cannot be described as electrons obeying the Heitler theory nor can an appreciable fraction be protons.

[1] Anderson and Neddermeyer, Phys. Rev. **50**, 263 (1936).
[2] Carlson and Oppenheimer, Phys. Rev. **51**, 220 (1937).
[3] L. Fussell, Jr., Abstract—Present meeting.
[4] C. G. and D. D. Montgomery, Phys. Rev. **50**, 975 (1936).

41. Production and Absorption of Cosmic-Ray Showers. L. FUSSELL, JR., *Massachusetts Institute of Technology and Harvard University*. (*Introduced by J. C. Street.*)—Cosmic-ray shower photographs taken with a large counter-controlled Wilson chamber[1] in which were mounted three horizontal lead scattering plates (0.63, 0.63 and 0.07 cm thick, from top to bottom, respectively, at a spacing of 6 cm) show that most showers develop and multiply in several successive steps. In the very thin plate pairs are frequently created, but the formation of larger groups has never been observed. Thus the recognized divergence of showers from a point in the bottom millimeter of a thick plate (0.5 cm or more) is misleading. The observations give strong support to the radiation, pair-formation theory of showers[2, 3] and show that complex showers are not developed at a single point except in rare cases. Three photographs out of nine hundred show showers of this type, different in that dense tracks and numerous thin ones are involved, and the appearance is such that the assumption of divergence from a single point well inside the lead can hardly be avoided. With no selecting counter above the chamber, 0.36 of the ordinary showers produced in the top plate seem to be due to electrons, the rest to non-

ionizing radiation. The average number of particles increases by a factor 1.7 in passing through the second plate.

[1] J. C. Street and E. C. Stevenson, Rev. Sci. Inst. **7**, 347 (1936).
[2] Heitler and Bhabha, Nature **137**, 401 (1936).
[3] J. F. Carlson and J. R. Oppenheimer, Phys. Rev. **51**, 220 (1937).

42. The Absorption of Cosmic Rays in the Atmosphere. L. W. NORDHEIM, *Purdue University*.—The recently developed laws of energy degradation of electrons and photons[1] are applied to the problem of the absorption of the cosmic rays in the atmosphere. Making allowance for a "hard component" of a nature different from electrons (necessary to account for the geomagnetic effect at sea level and the penetration into thick layers of heavy material) all other effects can be explained satisfactorily by identifying the "soft component" with electrons and photons which behave according to theory. A primary distribution of electrons can be found which gives the Regener absorption curve in the atmosphere, the geomagnetic effect at higher altitudes, the dependence of showers on latitude and altitude. The distribution of electron energies comes out to be nearly independent of altitude between sea level and $\sim$5000 m. This explains why the Rossi transition curves and the relative occurrence of showers of different size are nearly independent of altitude in this range. On the other hand it seems to be impossible to fit the facts with the assumption of a break down of the theory at very high energies and to identify the "hard component" with electrons which are too energetic to radiate because of such a break down.

[1] Carlson and Oppenheimer, Phys. Rev. **51**, 220 (1937); Bhabha and Heitler, Proc. Roy. Soc. A, in press.

43. Cosmic-Ray Showers from Lead Plates. ROBERT B. BRODE AND MERLE A. STARR, *University of California*.—Eight thousand counter tripped photographs have been taken of showers produced in lead plates of thickness 1.5, 4, 6.5, 9 and 16.5 mm placed in a Wilson cloud chamber. The sea-level cosmic-radiation passed through an equivalent of 10 mm of lead before reaching the lead plates. The number of pairs of electrons below the plate in the chamber produced by a charged particle entering from above rose rapidly with the thickness of the plate to a maximum at 5 mm and then fell to a nearly constant value for thickness greater than 9 mm. The number of pairs of electrons produced by photons was about equal to the number produced by charged particles and the thickness for the maximum number was about 5 mm. The optimum thickness for the production of 3 particles was about 6 mm. The probability of producing 5 or more particles from either a charged particle or a photon increases with the thickness without a maximum in the range of plates used in these experiments. The observed thickness for the maximum pair production in lead is in good agreement with the theoretical estimate made by Carlson and Oppenheimer.[1] A number of interesting showers have been observed and several cases of disintegration in which high energy heavy particles were ejected.

[1] Phys. Rev. **51**, 220 (1937).

44. Effect of Galactic Rotation upon the Intensity of Cosmic Radiation. W. F. G. SWANN, *Bartol Research Foundation of The Franklin Institute*.—The paper presents a mathematical theory of dependence of cosmic-ray intensity upon galactic rotation, discussed by A. H. Compton and I. A. Getting. The formulae obtained by Compton and Getting for neutral particles are deduced by processes closely analogous to the processes used by those authors. It is shown, however, that the extension to charged particles may be formulated in a manner which makes use of the modified form of Liouville's dynamical theorem, which has been found successful in other cosmic-ray problems, and the result is that the intensity at any point on the earth's surface is expressed in simple manner in terms of the direction of the orbit of the charged particle when traced back to infinity. Attention is called to the modification demanded by the theory of relativity in the intuitive picture of the phenomenon. The simple naive picture of what happens visions a stream of charged particles with the earth moving, for example, towards them. In this picture there is the alteration of relative velocity produced by the earth's motion, which is responsible for the change of intensity. The theory of relativity demands, however, a picture in which there is no alteration of relative velocity by the earth's motion, but where there is a change of particle density which conspires to produce a result the equivalent of that produced by change of relative velocity in the simple picture.

45. The Shadow Effect of Cosmic Radiation and Some Associated General Dynamical Theorems. E. J. SCHREMP, *Massachusetts Institute of Technology*.—Lemaitre and Vallarta have shown[1] that the cosmic-ray allowed cone is generated in part by orbits tangent to the earth's surface prior to their arrival at a given point of observation. A study of this class of orbits with Bush's differential analyzer has led to the formulation of certain general theorems concerning this nonintegrable dynamical problem: When $0.78856 < \gamma_1 < 1$,[2] there exist two principal periodic orbits, between which all re-entrant orbits cross the equator within a definite pencil of directions. Since these orbits are either periodic or come indirectly from infinity, all orbits arriving at a given point come from infinity, except those blocked by the earth and the totality of periodic orbits, which form a set of zero measure. The determination of the penumbral regions thus reduces to the shadow effect of re-entrant orbits. Since the principal periodic orbits vanish together when $\gamma_1 = 0.78856$, all re-entrant orbits, and in particular all periodic orbits, vanish with them. Thus when $\gamma_1 < 0.78856$, all orbits come directly from infinity, and there is no penumbra. By a similar theorem, for all points of observation and a given energy, there is a maximum $\gamma_1 \leqq 1$ beyond which no penumbral allowed directions exist.

[1] G. Lemaitre and M. S. Vallarta, Phys. Rev. **50**, 493 (1936).
[2] For the definition of the parameter γ_1, cf. reference 1.

Thursday Afternoon at 2:00 o'clock

National Bureau of Standards

Chemistry Building, Lecture Room

46. The Electric Spectrum of Liquid Water from Five to Twenty Centimeters. Henry W. Knerr, *Pennsylvania State College.*—Continuous electromagnetic radiation with wave-lengths ranging from five to twenty centimeters was produced by a magnetron generator. Nineteen different wave-lengths in this region were used in the measurement of refractive index and absorption index of liquid water. A free wave method and a wire wave method suggested by the experiments of Seeberger* were set up and studied. The wire wave method gave surprisingly consistent results for this difficult region of the spectrum. A good agreement was secured between results obtained by the two methods. The details of these methods will appear in an early publication. No evidence of dispersion was found in this region, the refractive index at 22°C being 8.79 with no observation deviating more than 0.8 percent from the mean. This value is about 1.5 percent smaller than the value for long radio waves but shows no tendency to decrease toward infrared values. The absorption index increased steadily from 0.048 at 20.44 cm to 0.153 at 4.80 cm. The relaxation time was calculated from the Debye theory and found to be of the order of 7×10^{-13} sec.

* M. Seeberger, Ann. der Physik (5) **16**, 77 (1933).

47. The Isotopic Constitution of Mercury and Lead. Alfred O. Nier,* *Harvard University.*—A new magnetic mass-spectrograph has been constructed for the purpose of making accurate determinations of the relative abundance of isotopes. The high intensity and high resolving power of the apparatus allow the search for rare isotopes to be extended beyond previously attainable limits. An investigation showed mercury to consist of the isotopes 204, 202, 201, 200, 199, 198, and 196 present in abundances proportional to the numbers 22.7, 100, 44.6, 78.7, 57.6, 34.2, and 0.50, respectively. The following upper limits can be set for other isotopes: Hg^{206} and Hg^{205}, 1/4000 of Hg^{204}; Hg^{203}, 1/5000 of Hg^{202}; Hg^{197}, 1/40 of Hg^{196}; Hg^{195} and Hg^{194}, 1/100 of Hg^{196}. A sample of ordinary lead kindly provided by Dr. v. Grosse was found to consist of the isotopes 208, 207, 206 and 204. Exact values of the isotope abundances will be published after additional data have been taken on ordinary lead from different sources and geographical locations. A search for Pb^{210}, Pb^{209}, Pb^{205} and Pb^{203} showed that if these isotopes exist at all it must be in amounts less than 1/100, 1/1000, 1/3, and 1/20, respectively, of the abundances given for them by Aston.

* National Research Fellow.

48. Separation of Isotopes by Diffusion. Rubby Sherr, *Princeton University.*—Further investigations have been carried out on the system of diffusion pumps reported last year. A modification of Hertz' design was made in the construction of additional pumps in an attempt to obtain a mercury vapor jet more conducive to separation. Tests on eight new pumps gave a separation factor as high as 40 for a mixture of CO_2-A, for an initial ratio CO_2/A of 1/10. Calibration tests on the composite system of 29 pumps indicate a factor of 144 for the neon isotopes, the yield from 100 cc being 1.5 cc containing about 80 percent Ne^{22}, the system coming to equilibrium within 10 hours. Preliminary runs on methane indicate a factor of 10, the yield being 1.5 cc containing between 5 and 5.5 percent $C^{13}H_4$. By using a larger reservoir at the "light" end or by renewing the gas in order to keep the concentration up to its initial value, one can expect an enriched concentration of 10 percent.

49. The Products of Dissociation of Benzene Vapor by Electron Impact. P. Kusch, J. T. Tate, and A. Hustrulid, *University of Minnesota.*—The dissociation of benzene vapor by electron impact has been investigated on a mass-spectrograph. At an electron energy of 75 volts the ions which have been identified and their intensities relative to the ion $C_6H_6^+$ as 100 are as follows: $C_6H_6^+$, 100; $C_6H_5^+$, 17; $C_6H_4^+$, 5; $C_6H_3^+$, 2; $C_6H_2^+$, 4; C_6H^+, 1.3; C_6^+, 0.25; $C_5H_3^+$, 2.5; $C_5H_2^+$, 0.6; C_5H^+, 0.5; C_5^+, 0.02; $C_4H_4^+$, 13; $C_4H_3^+$, 15; $C_4H_2^+$, 12; C_4H^+, 2; C_4^+, 0.3; $C_3H_3^+$, 6.7; $C_3H_2^+$, 3; C_3H^+, 2.5; C_3^+, 0.3; $C_2H_3^+$, 1.4; $C_2H_2^+$, 1.2; C_2H^+, 0.15; C_2^+, 0.03; CH_3^+, 0.2; CH_2^+, 0.02; CH^+, 0.03; C^+, 0.05; H_2^+; H^+; $C_6H_6^{++}$, 3.3; $C_6H_5^{++}$, 0.4; $C_6H_4^{++}$; $C_6H_3^{++}$, 0.9; $C_6H_2^{++}$; C_6H^{++}, 0.01. Some of these ions appear as doublets whose components have a constant energy separation independent of magnetic field. The components of these doublets have different appearance potentials. This would seem to indicate that these ions may be formed by either of two processes, one of which imparts considerable kinetic energy to the ions. Appearance potentials of some of the ions have been obtained.

50. Stark Effect in Argon and Krypton. J. S. Foster and C. A. Horton, *McGill University.* (*Introduced by Professor G. B. Pegram.*)—In a field of 100 kv/cm Stark effects have been observed for 86 normal levels in argon and for 75 in krypton. It has been found that the number of Stark levels is never greater than the number of $\pm m$ values allowed by the j-value of the term. The reversal of the direction of displacement of several terms in both gases with increasing field is discussed. Typical sections of the energy level diagrams for Ne, A, Kr, and Xe are drawn to represent the normal levels and their Stark effects. These diagrams serve as a basis for the qualitative explanation of the main features observed. Several lines in the arc spectra of argon and krypton are identified by their Stark effects. Certain corrections to the earlier work of Ryde are suggested. The full paper will appear shortly.

51. Shot Effect of Secondary Electron Currents from Nickel and Beryllium. Bernhard Kurrelmeyer, *Brooklyn College* and Lucy J. Hayner, *Columbia University.*—The

study of secondary emission shot effects of oxide-coated surfaces* has been extended to clean nickel and beryllium. The nickel was commercial sheet, the beryllium a thick layer evaporated in high vacuum. The tubes were cylindrical triodes having axial tungsten filaments. The ratio of plate (emitter) to grid (collector) voltage was kept constant. The shot effects were measured at 110 kilocycles, using temperature-limited shot effects as standards. The maximum primary energy was 1600 volts, well beyond the maximum of the secondary emission curves for both metals. The maximum secondary-primary ratios observed were 1.3 (nickel) and 4.4 (beryllium). For both metals the secondary shot effects increase continuously with the primary energy. In terms of the shot effect of equal temperature-limited currents, the secondary shot-effect values were about 3.2 (nickel) and 7.2 (beryllium) at their respective maximum secondary emissions, or 3.9 and 9.3 at 1600 volts primary energy. These results will be interpreted in terms of absorption and scattering of primary and secondary electrons within the metal. This work was done during the summers of 1935 and 1936 at the University of Michigan.

* L. J. Hayner, Physics 6, 323 (1935).

52. Secondary Emission from Clean Tungsten. EDWARD COOMES, *Massachusetts Institute of Technology. (Introduced by W. B. Nottingham.)*—The secondary electron emission from clean tungsten has been investigated over an energy range for primary electrons of 50 to 2000 volts. Measurements were taken on a sealed-off tube. The primary beam was supplied by an electron gun of the cathode ray tube type; the beam was passed through slits and brought to focus on the target by means of an electrostatic lens. A slight deflection by a magnetic field allowed the visual observation of the position of the primary beam on a fluorescent screen placed immediately behind the target; during actual measurements the beam could be so well focused that the screen current was generally less than 0.1 percent of the primary current. The metal parts were constructed of tantalum, which allowed thorough outgassing. The target consisted of a tungsten ribbon, which was cleaned by long period heating at 1800°K and flashing at 2600°K. The ratio of secondary to primary current as a function of primary voltage mounts from 0.53 at 50 volts to a flat maximum of 1.28 at 475 volts; it slowly falls to unity at 1325 volts and reaches a value of 0.93 at 2000 volts. All measurements were taken with a cold target, and tests for reproducibility were carried out over a 48-hour period after flashing. No changes in the secondary emission characteristic were observed. An increase in secondary emission has been observed when thorium is evaporated onto the clean tungsten.

53. Electrical and Luminescence Properties of Willemite Screen Material. W. B. NOTTINGHAM, *Massachusetts Institute of Technology.*—A willemite screen was deposited on a glass surface containing two embedded fernico wires. With the fluorescence excited by an electron beam focused to cover the plate, the surface potential, resistivity and luminous output were determined. The surface potential of the screen differed very little from that of the anode for potentials below about 6000 volts depending on the particular sample. With anode voltages higher than this, the screen potential relative to the cathode tended to hold at a fixed value determined by the highest primary electron voltage for which one secondary electron was produced for each primary arriving at the screen. Up to this voltage, using a constant current to the screen, the light output was represented by $L=Q(V-V_0)^2$, where L is the phototube current, Q a constant nearly proportional to the beam current and V_0 the dead voltage which depends on the particular sample. The range of V_0 observed was from nearly zero to about 400 volts. The surface resistivity of the phosphor determined for one sample was approximately 300 megohms assuming the resistance of the sample studied was proportional to the distance between the fernico wires and inversely proportional to the lengths of the wires in contact with the phosphor.

54. Propagation of Potential in Discharge Tubes. L. B. SNODDY, J. R. DIETRICH AND J. W. BEAMS, *University of Virginia,*—The determination of the speed of propagation of potential waves in long discharge tubes has been continued using essentially the same type of apparatus as that previously described.[1, 2] Average speeds over an 8.5 meter section of a 16 meter tube have been determined for three tubes (internal diameter 1.7, 5 and 18 mm. Pressure range 0.02 mm to 5 mm. 125 kv impulse). With each tube the speed increases rapidly in the pressure range from 0.02 mm to about 0.2 mm. At higher pressures the rate of increase is much slower. The speed increases with increasing tube diameter at constant voltage and pressure. At 0.8 mm pressure the values are 24×10^8, 32×10^8 and 46×10^8 cm/sec. for diameters of 1.7, 5, and 18 mm respectively. The speed for negative impulses is approximately twice that for positive (measured only for 18 mm tube). The speed as a function of voltage at constant pressure (0.4 mm) is approximately linear in the voltage range from 70 kv to 190 kv. Dry air was used for all determinations.

[1] Phys. Rev. 50, 469 (1936).
[2] Phys. Rev. 50, 1094A (1936).

55. Recombination in the Afterglow of a Discharge. FRED L. MOHLER, *National Bureau of Standards.*—A discharge of 6 amperes or less through a 500 cm³ bulb with electrodes in side tubes was extinguished by short-circuiting with a motor-driven commutator, and electrical measurements were made of the number of ions per cm³ near the center of the bulb and the flow of current to the walls at time intervals ranging from 5×10^{-4} to 6×10^{-3} seconds after the cut-off. The change in the number of ions in the bulb in a given time interval is equal to the number flowing to the walls plus the number recombining in the space. Hence one derives the recombination coefficient, α, defined by the relation dn/dt (recombination) $=-\alpha n^2$ where n is the number of ions of either sign per cm³. Measurements made with a thermionic discharge in cesium vapor in the pressure range 8μ to 100μ give a value of $\alpha=3\pm1\times10^{-10}$ with an electron temperature about 1200°K. Measurements with a mercury arc at pressures of 50 and 290μ give $\alpha=2\pm0.5\times10^{-10}$ with an electron temperature of about 2000°K. With an ion concentration of 10^{12} the recombina-

tion loss and wall effect are of the same magnitude for the volume and pressure range used and the relative change in concentration of ions is approximately 50 percent in 10^{-3} seconds.

56. Potentials in the Intermittent Glow Discharge. LESTER BOCKSTAHLER AND HERMAN RITOW, *Northwestern University.*—A steady current supplied to an electrical condenser in parallel with a pair of electrodes in a partial vacuum of a few mm pressure gives rise to an intermittent glow. Potentials between the electrodes have been measured when (a) the initial glow appears, (b) the discharges strike during the intermittent glow, (c) the discharge is extinguished, and (d) the glow breaks into an arc. The potential for the initial discharge is constant for a given set of electrode and pressure conditions. The striking potential of the intermittent glow decreases with increasing charging current. The extinction potential is a constant. One cm aluminum electrodes (plane circular anode, conical cathode with vertical angle 60 deg.) separated 2 cm in hydrogen were used. An attempt is being made to explain the "effective" tube capacity of such a glow in terms of the residual ions between individual discharges which influence the striking potentials.

FRIDAY MORNING AT 9:30 O'CLOCK

National Bureau of Standards

Industrial Building, Room 301

57. Magnetic Hysteresis in 35 Permalloy Sheet at Low Flux Densities. W. B. ELLWOOD, *Bell Telephone Laboratories, Inc.*—The energy loss per cycle in a ferromagnetic material subjected to small alternating fields is sometimes separated into three parts. The first is due to eddy-current loss; the second to hysteresis presumed to follow Rayleigh's law. The third is a residual of doubtful origin and has been variously termed "magnetic viscosity," "after effect," and "square law hysteresis." The search for an explanation of this residual loss has led to a more accurate review of the methods of measurement. To compare the a.c. losses with the ballistic hysteresis loop at the same flux densities, a new ballistic method has been developed with a relative precision in B_m of 0.01 percent. The method originally applied to a compressed iron dust ring of low permeability has been improved and used to study the properties of a well-annealed spirally wound roll of permalloy (35 percent Ni) sheet which has a very large residual loss. The hysteresis loops studied range from $B_m = 1.3$ to $B_m = 5.3$ gauss. They are lenticular and very slender, B_r being about 900 times the remanence for the smallest loop. The energy loss per cycle is proportional to B_m^3 and the proportionality factor agrees with the value inferred from the a.c. measurements assuming Rayleigh's law. No residual loss was found by the ballistic method.

58. Low Flux Density a.c. Losses in 35 Permalloy Sheet. V. E. LEGG, *Bell Telephone Laboratories, Inc.*—In making precise a.c. bridge measurements on a coil wound on a laminated 35 permalloy core, both the resistance and inductance are found to vary with frequency in a manner not predicted by classical theory. From the resistance measurements, the losses are separated in the usual way into hysteresis, eddy current and residual components. The hysteresis loss per cycle is found to be independent of frequency, and to agree with that obtained by ballistic galvanometer measurements (see above abstract). The eddy current loss coefficient observed in the range 500~ to 10,000~ is approximately 15 percent larger than computed from classical theory, and it appears to increase as the frequency decreases. The residual loss coefficient is found to be approximately constant at higher frequencies, but to decrease toward zero as the frequency approaches zero. Since excess eddy current and residual losses are both proportional to B_m^2, they are examined together as of possible common origin, and in relation to the anomalous inductance-frequency characteristic. This characteristic consists of a more rapid decline of inductance with frequency than predictable from the theory of eddy current shielding.

59. Magnetic Properties of Single Crystals of Silicon Iron. H. J. WILLIAMS, *Bell Telephone Laboratories, New York, N. Y.*—Single crystals of iron containing 3.9 percent silicon have been prepared and the magnetic anisotropy constants determined in three ways: (1) by determining the magnetization curves in the [100], [110] and [111] directions and measuring $\int HdI$ for each curve, (2) by fitting the theoretical magnetization curves to the data using the values of the constants that give the best fit, (3) measuring the torque upon a single crystal disk cut parallel to a (110) plane, in a magnetic field, as dependent upon the orientation of the disk in the field. The values of the constants so determined agree rather well and are $K_1 = 305{,}000$, $K_2 = -200{,}000$, in ergs/cm³. Measured in the [100] direction, the maximum permeability was 620,000, the coercive force 0.03 oersted.

60. Single Crystals with Exceptionally High Magnetic Permeabilities. P. P. CIOFFI, H. J. WILLIAMS, AND R. M. BOZORTH, *Bell Telephone Laboratories, New York, N. Y.*—Single crystals of purified iron and of an iron-nickel alloy containing 66 percent nickel have been prepared and some of their magnetic properties measured. For iron the maximum permeability was 680,000 measured at $B = 17{,}800$. The highest permeability reached for the alloy was 1,040,000, and was attained by combining several factors,

each one of which is known to favor high permeability. These factors are: (1) Absence of strains associated with hard-working, dissolved impurities and grain boundaries; (2) choice of a proper crystallographic direction for magnetization; (3) presence of a magnetic field (in the direction chosen for test) during annealing; these are of unequal importance in different ferromagnetic metals and alloys so we may add: (4) appropriate composition. The materials were heat-treated in pure hydrogen just below the melting point. The specimens were cut in the form of hollow rectangles so oriented that each edge was parallel to a tetragonal axis and so to a direction of easy magnetization. Thus a closed magnetic circuit, necessary for accurate high permeability measurements, was obtained.

61. Magnetic Anisotropy in Silicon Steel. W. E. INGERSON AND F. J. BECK, JR., *Yale University.*—A new method, which provides a convenient and rapid means of studying ferromagnetic anisotropy, has been developed. A specimen in the form of a circular disk placed in a uniform field with H in the plane of the specimen is rotated at uniform speed within a stationary search coil. The search coil, which can be turned so that its axis is in any radial direction, is connected through an integrating circuit and a linear amplifier to a D'Arsonval oscillograph. Oscillograms taken with the search coil axis parallel and perpendicular to the field represent the cyclic variation of the intensity of magnetization in these directions, ($\Delta I_{\parallel}$) and ($\Delta I_{\perp}$). The constant component of the intensity of magnetization (I_c) is determined ballistically with the disk rotating. Vectorial addition of $\Delta I_{\parallel}$, $\Delta I_{\perp}$, and I_c determines I for all magnitudes and directions of applied field. A sample of the silicon steel developed by Goss[1] has been investigated by this method. The $\Delta I_{\perp}$ curves are shown to correspond to torque-angle curves obtained by previous investigators, and to agree with the percentage orientation as determined by crystal count. The addition of $\Delta I_{\parallel}$ and I_c gives magnetization curves in the directions of symmetry, which are found to be 0, 55, and 90 degrees from the rolling direction.

[1] N. P. Goss, Trans. A. S. M. E. **23**, 511 (1935).

62. The Relation of Ferromagnetic Anisotropy to Atomic Structure. L. W. MCKEEHAN, *Yale University.*—The mutual potential energy of an unstrained crystal with equal magnetic elements at lattice points depends upon the distribution of magnetic moment in each element, upon the crystal structure, and upon the direction of the magnetic axes, supposed to be parallel. The dependence upon direction accounts for ferromagnetic anisotropy. Ferromagnetic atoms of iron, cobalt and nickel are now assigned simple distributions of magnetic moment, consistent with what is known about 3*d* electrons in these atoms, and the resultant anisotropy calculated to and including sextupole terms for the cubic and hexagonal arrangements observed to occur. The results are qualitatively in agreement with reported experimental results concerning these three metals and their solid solutions. The probable effect of heat motions in modifying the anisotropy improves the quantitative agreements.

63. An X-Ray Study of the A_{r_3} and A_{c_3} Points for Pure Fe and Fe-Ni Alloys. SIDNEY D. SMITH AND WHEELER P. DAVEY, *Pennsylvania State College.*—Roberts and Davey[1] reported a reversible A_3 point (between 907 and 910±3°C) for pure iron and gave data for irreversible A_{c_3} points for pure iron nickel alloys. The present work sets closer limits (between 907 and 908±2°C) on the A_3 point for pure iron, and gives both A_{c_3} and A_{r_3} points for pure iron-nickel alloys up to 5½ percent nickel. The A_{c_3} points found differed slightly from those of Roberts and Davey, probably because of the well-known difficulties of analysis of iron-nickel alloys, but the discrepancies are not at all serious. The graphs of the present data indicate an almost uniform difference of about 15 percent between the A_{r_3} and the A_{c_3} points for nickel contents of from 1 to 5½ percent nickel. This work was materially aided by a grant from the National Research Council Committee on Grants-in-Aid for making possible the purchase of certain necessary equipment.

[1] Metals and Alloys 1, 1 (1930).

64. Magnetic Experiments at Very Low Temperatures. F. SIMON, *Oxford University.* (Invited paper.) 20 minutes.

FRIDAY MORNING AT 9:30 O'CLOCK

National Bureau of Standards

East Building, Lecture Room

65. A Photoelectric Method for Tracing Current Wave Forms. W. S. HUXFORD, *Northwestern University.*—A photoelectric timing arrangement is used to obtain point by point plots of periodically varying currents. The circuit contains a three-electrode vacuum photo-cell in which electron emission occurs only when a short flash of light enters the cell through a narrow slit in a disk driven by a synchronous motor. The interval of the light flash is 50 micro-seconds. The potential set up by a current flowing in a non-inductive resistance is applied to the control grid of the photo-triode. The average value of this potential taken over the interval of the light flash is measured by means of a potentiometer. The "phase" of the light flash can be changed by rotating the motor in its geared housing. Potential differences of 0.001 of a volt are easily detected, the limit of error in the measured values of points on the wave plot being of the order of ±0.005 of a volt. The method is of particular value for the delineation of small current and potential changes, the amplification of which may result in serious distortion when a cathode ray

oscillograph is used. Wave forms are shown for a.c. metal arcs, copper oxide rectifiers, and for the lag of current with time in gas-filled photo-cells.

66. Deuteron Bombardment of Barium, Lanthanum and Cerium. M. L. POOL* AND J. M. CORK, *University of Michigan.*—These three elements of atomic numbers 56, 57 and 58 respectively have been bombarded in the cyclotron by 6.5 million volt deuterons. Barium becomes strongly radioactive with a half-life period of 85.6 min. The β-particles have the negative sign. Chemical analysis shows that the activity is most probably due to Ba^{139}. The single stable lanthanum isotope, 139, gives a radioactivity with a half-life period of 31 hours. The β-particles also have the negative sign. In the chemical analysis of the disintegration products lanthanum was separated from cerium by the bromate method. The activity is attributed to La^{140}. A Konopinski-Uhlenbeck plot, based upon a thousand Wilson cloud chamber tracks, has been made of the β-emission. When cerium is bombarded, a 2.4 hour period is obtained. Traces of various easily activated light element impurities have been quite troublesome in this work. The two rare earth elements were kindly prepared and purified for us by Professor L. L. Quill of the Ohio State University.

* Elizabeth Clay Howald Scholar.

67. Radioactivity in Iron by Deuteron Bombardment. B. T. DARLING, B. R. CURTIS AND J. M. CORK, *University of Michigan.*—Chemically pure electrolytic iron has been bombarded in the cyclotron with a beam of deuterons of 6.3 Mev energy. After bombardment chemical separations were made to identify the active isotopes formed. The cobalt precipitate shows a very strong positive activity of half-life 18.2 hrs. This corresponds to the capture of a proton with the probable ejection of a neutron. The manganese precipitate shows an activity whose half-life is 21 min. This indicates the capture of the deuteron with the ejection of an alpha-particle. (This precipitate also shows the ordinary manganese period 2.5 hrs. when commercial impure iron is used.) No activity of half-life long enough to be observed after the chemical separation could be found in the iron itself due to neutron capture. The energies of the beta and gamma radiations have been determined.

68. The Disintegration of Lithium by Deuterons. J. H. WILLIAMS, W. G. SHEPHERD AND R. O. HAXBY, *University of Minnesota.*—The following disintegrations have been investigated from 100 kv to 250 kv deuteron energy.

$$Li^6+H^2 \rightarrow He^4+He^4, \quad (1)$$

$$Li^6+H^2 \rightarrow Li^7+H^1, \quad (2A)$$

$$Li^6+H^2 \rightarrow Li^{7*}+H^1, \quad (2B)$$

$$Li^7+H^2 \rightarrow He^4+He^4+n^1. \quad (3)$$

Efficiency curves for these reactions show that increasing deuteron energy causes a less rapid increase in yield for (1) than for (2A) contrary to the simple interpretation of the theory of Oppenheimer and Phillips.[1] The yield of alpha-particles of 2.8 cm range differentially selected from the continuous energy distribution of (3) rises even more rapidly with deuteron energy. Qualitative results on the disintegrations per deuteron of 212 kv energy from a thick Li target assuming isotropic angular distribution are: (1) 2.7×10^{-9}; (2A) 1.1×10^{-8}; (2B) 3.5×10^{-9}; (3) 6×10^{-7}. The relative yield of protons from (2B) to (2A) decreases in a linear manner by approximately 25 percent from 250 kv to 100 kv. A search for the gamma-ray of 400 kv energy corresponding to the return of Li^{7*} in (2B) to its normal state indicates a positive result.

[1] Oppenheimer and Phillips, Phys. Rev. **48**, 500 (1935); Rasetti, "Elements of Nuclear Physics," page 251.

69. The Radioactivities of Bromine. ARTHUR H. SNELL, *University of California.*—Although bromine possesses only two isotopes, Br^{79} and Br^{81}, it is known to give rise to three neutron-induced radioactivities, with decay periods 18 minutes, 4.2 hours, and 35 hours. The same three activities are now found to be induced when bromine is activated with deuterons. The 18 minute and the 35 hour activities are accompanied by γ-rays, but the 4.2 hour period has none. When arsenic is bombarded with artificially accelerated α-particles, another active bromine results. It emits positrons with a decay period of 6.3 minutes, and is described presumably by the reactions $_{33}As^{75}+_2He^4=_{35}Br^{78}+_0n^1$ and $_{35}Br^{78}=_{34}Se^{78}+e^+$. The identification has been checked chemically. Still another bromine appears in a chemical separation from selenium activated with deuterons. It has a period of 2.5 hours and is attributed to Br^{83}, the reactions being:

$$(1) \quad {}_{34}Se^{82}+{}_1H^2={}_{35}Br^{83}+{}_0n^1,$$

$$(2) \quad {}_{34}Se^{82}+{}_1H^3={}_{34}Se^{83}+{}_1H^1,$$

$${}_{34}Se^{83}={}_{35}Br^{83}+e^-,$$

and

$${}_{35}Br^{83}={}_{36}Kr^{83}+e^-.$$

(Se^{83} has a period of 10–20 minutes.) There is good evidence for the double β-decay indicated in (2). The 35 hour activity also appears in this separation. These results seem at present to indicate that the 18 minute, 4.2 hour, and 35 hour activities must all belong to Br^{80} and Br^{82}, i.e., one of these isotopes appears to exist in two isomeric forms, from which it decays with different periods.

70. The Induced Radioactivity of Titanium. HAROLD WALKE,* *University of California, Berkeley.*—Under bombardment with 5.5 Mev deuterons titanium metal has been rendered strongly radioactive. Analyses of the gamma-ray decay curve indicate the formation of radioactive bodies with half lives of 2.8 ± 0.1 minutes, 33 ± 2 minutes, 15.7 ± 0.7 hours and 16.2 ± 0.4 days. The short lived isotope is probably Ti^{51}, for the radioactivity induced in titanium with slow neutrons decays with a half life of 2.9 ± 0.1 minutes. The 33 minute period may be due to V^{49} or V^{50} as a period of 35 ± 2 minutes was also observed when titanium was bombarded with 11 Mev alpha-particles. Thus we have:

$$Ti^{48,\,49}+H^2 \rightarrow V^{49,\,50}+n^1,$$

$$Ti^{46,\,47}+He^4 \rightarrow V^{49,\,50}+H^1.$$

The isotope with the half life of 15.7 hours emits high energy electrons and strong gamma-radiation and may be

due to sodium contamination. The isotope with half life 16 days, however, emits positrons of energy 1.2 Mev. This radioactive body is probably an isotope of vanadium formed thus: $Ti^N+H^2 \rightarrow V^{N+1}+n^1$. Under bombardment with 11 Mev alpha-particles, periods were observed with values 35 ± 2 minutes, 2.7 ± 0.2 hours, 5.5 ± 0.3 hours and 85 ± 10 days. With fast neutrons two new periods of 2.3 ± 0.2 hours[1] and 18 ± 2 hours were detected.

* Commonwealth Fellow.
[1] Walke, Phys. Rev. **51**, 439 (1937).

71. A Discharge Tube Ion Source for the Cyclotron. C. P. BAKER AND M. STANLEY LIVINGSTON, *Cornell University.*—A capillary discharge tube has been developed to serve as a cyclotron ion source. The metal capillary (3/16" I. D., 1/4" O. D.) is mounted vertically in the center of the cyclotron between parallel tubes for anode and filament. A small hole (1 mm) drilled through the capillary wall provides an exit for the ions and gives a pressure differential between the arc (H_2 at $\sim10^{-2}$ mm) and the cyclotron chamber ($\sim10^{-5}$ mm). An arc of 2–5 amperes can be maintained between anode and cathode with an arc drop of about 100 volts, in the magnetic field of the cyclotron. Ions are pulled out of the hole by the high frequency field of the cyclotron or swept out by the gas flow. Calculations show that the initial spiral path of the ions allows them to clear the 1/4" tube. With an emergent ion current of 20 microamperes a high voltage beam of 1 microampere is obtained. Possibilities of improving the emergent ion current (in one design 500 microamperes) suggest that much higher intensities are available. The chief advantages are in the point source of ions and consequent improvement of the energy distribution of high voltage ions, and elimination of heating effects from filament sources.

72. Stopping of the Recoil Electrons Produced by the $F+H^1$ Gamma Rays. J. J. TURIN AND H. R. CRANE, *University of Michigan.*—The recoil electrons produced by the 6 Mev gamma radiation from fluorine bombarded with protons were allowed to pass through 5 mm carbon and ½ mm lead absorbers placed across the center of a cloud chamber. The curvatures of the incident and emergent tracks in the magnetic field were measured, the difference giving the loss in passing through the absorber. Results on a total of 448 tracks are given in the table below.

ABSORBER	INCIDENT ENERGY	AVERAGE LOSS
5 mm carbon	2 to 4 Mev	1.70 Mev
5 mm carbon	4 to 6 Mev	1.73 Mev
½ mm lead	2 to 4 Mev	1.41 Mev
½ mm lead	4 to 6 Mev	1.73 Mev

The losses in carbon are in good agreement with the theoretical losses due to electron collisions, and this is satisfactory, since no radiative losses are expected in a substance of such low atomic number. In the case of lead, the data show clearly that radiative losses play a large part, and increase with increasing energy of incident particle. The losses found in lead are somewhat greater than those predicted by theory, but it may be possible to account for this by errors in the experiment.

73. Experiments on Li^8 and B^{12}. D. S. BAYLEY AND H. R. CRANE, *University of Michigan.*—We have attempted to make precise measurements of the upper limits of the Li^8 and B^{12} beta-ray spectra by the cloud chamber method. The path of the particles in the magnetic field was such that only those above 9 Mev were able to enter the chamber, which allowed us to work with a large intensity near the upper limit. The cut-off appears to be 12 Mev for both spectra. Excitation curves for the two reactions

$$(1)\quad Li^7+H^2 \rightarrow Li^8+H^1,$$
$$(2)\quad B^{11}+H^2 \rightarrow B^{12}+H^1$$

were compared. Reaction (1) seemed definitely to have a threshold between 400 and 450 kv deuteron energy, while reaction (2) extended at least as low as 300 kv. This probably indicates that the proton emitted in reaction (1) has very little energy, perhaps 0.1 or 0.2 Mev at 400 kv bombarding energy. On this assumption we can fill in the missing link in the energy equation and write it

$$Li^7+H^2+0.4\text{ Mev} \rightarrow Li^8+H^1+0.2\text{ Mev};$$
$$Li^8 \rightarrow (Be^8)+e^- \rightarrow 2He^4+e^-+15\text{ Mev}.$$

Assigning 12 Mev to the beta-particle, 3 Mev is left for the two alpha-particles, which agrees with the most probable energy found by Delsasso, Fowler and Lauritsen.[1] As an explanation of the continuous nature of the alpha-particle distribution found by Lewis, Burcham and Chang,[2] we suggest that the lifetime of the daughter nucleus Be^8 for disintegration into two alpha-particles is so extremely short that the level is practically a continuum and the beta transition may sometimes occur so as to leave the alpha-particles with nearly all of the energy.

[1] Phys. Rev. **51**, 399 (1937).
[2] Nature **139**, 24 (1937).

74. The Capture of Protons by Oxygen. L. A. DUBRIDGE, S. W. BARNES, AND J. H. BUCK, *University of Rochester.*—The capture of protons of various energies by oxygen leading to the production of radiofluorine has been investigated with the cyclotron. The reaction sets in at a proton energy of about 1.4 Mev rising sharply as far as 2.5 Mev. Measurements are under way at higher energies. The preliminary measurements on the period of the radiofluorine give a value of 1 minute 21 seconds. This is slightly higher than previously reported values for radiofluorine produced in other reactions, a discrepancy which is being investigated. There is some suggestion of the presence of a considerably longer period produced by a reaction not yet definitely identified. The measurements have been made using a solid target of quartz and also by collecting recoil atoms on a platinum foil in oxygen.

75. Resonance Transmutation of Se(34) by Protons. J. H. BUCK, C. V. STRAIN, AND G. VALLEY, *University of Rochester.*—The excitation function for induced radioactivity of Se has been examined experimentally over the range from 1.7 to 3.6 Mev. Measurable activity is found to begin at 2.3 Mev and to increase very sharply at about 3.1 Mev. This excitation curve is compared with others taken for neighboring elements.

Friday Afternoon at 2:00 o'clock

National Bureau of Standards

East Building, Lecture Room

76. Proton-Induced Radioactivity of Elements of Atomic Number Greater than Eleven. S. W. Barnes, L. A. DuBridge, E. O. Wiig, J. H. Buck, and C. V. Strain, *University of Rochester.*—Si, K, Ca, Ti, Cr, Mn, Co, Ni, Zn, As, Se, Cd, In, Sn, and Sb have been found to become radioactive under a bombardment of 3.6 Mev protons. Mg, Al, S, Cl, Fe, Cu, and Ag show no signs of induced activity under the same conditions. The relative activity of the members of the first group is 6, 38, 21, 30, 5, 27, 6, 21, 40, 13, 2000, 10, 20, 3, 2, and 1. Preliminary measurements of the periods have been made and it is found that only Mn(11.3 min.) and Co(14.3 min.) yield products having a single period. Identification of the products of the reactions cannot be made from the periods, since practically none of the active substances have been reported previously. A program of identification by chemical separations is under way.

77. The Production of High Energy Alpha-Particles by the Princeton Cyclotron. M. G. White, M. C. Henderson, W. J. Henderson, and L. N. Ridenour, *Princeton University.*—Doubly charged helium ions have been accelerated in a cyclotron to 9 MV at a current of 0.05 microampere. The optimum helium pressure is about 10^{-4} mm Hg with a radiofrequency power input of 5 kw to the oscillatory circuit. Oscillographic studies of the wave shape of the ion beam indicate that a current of at least 0.3 microampere should be available when d.c. power for the oscillators is substituted for the present unrectified a.c. The difference between the m/e for helium ions and for hydrogen mass two ions is sufficient to permit an almost complete separation of the helium beam from possible deuteron contamination. To make more certain of freedom from this contamination deuterium has never been used in the Princeton cyclotron. By electrostatic deflection the high velocity ion beam has been brought outside the vacuum chamber. A set of graded stopping foils for altering the energy of the ions has been arranged to operate in vacuum.

78. Radioactivity Induced by Alpha-Particles. L. N. Ridenour, W. J. Henderson, M. C. Henderson, and M. G. White, *Princeton University.*—The artificial radioactivity produced by the bombardment of light elements with 0.05 microampere of 9 Mev alpha-particles produced by the Princeton cyclotron has been studied. This alpha-particle beam is equivalent to that from 4 curies of ThC′. Preliminary results indicate that the accepted value of the half-life of P^{30} (3.3 minutes) is in error; measurements with the strong sources available to us give a half-life of 2.52 ± 0.05 minutes. Half-life measurements on other artificial radioelements produced by alpha-particle bombardment are summarized below.

Target	Active Isotope	Half-life
B	N^{13}	10.5 min.
N	F^{17}	69 sec.
Al	P^{30}	2.52 min.

Measurement of the energy-yield curves of the reactions producing these radioelements is in progress.

79. Long-Period Radioactivity in Cobalt Induced by Slow Neutrons. J. R. Risser, *Princeton University.*—Sampson, Ridenour and Bleakney[1] found an activity in cobalt after exposure to slow neutrons with a period of about a year. This activity is quite strong, considering the long mean life, and is perhaps to be attributed to the more abundant isotope, Co^{59}. The only other known activity induced in Co by slow neutrons, a 20-minute period observed by Rotblat, can be attributed to the less abundant isotope Co^{57}. The long-period activity has been investigated further. It is found that the response of even a thin-walled beta-ray counter is due to gamma-rays alone. By the use of a wire screen counter, with the cobalt and thin aluminium absorbers in the same envelope with the counter, particles emitted with low energies have been found. The aluminium screens were manipulated by a magnetic device from the outside and the absorption indicated that the upper limit of these soft beta-rays cannot be much greater than 150 kv. Preliminary absorption measurements in both lead and copper indicate that a gamma-ray of energy of the order of 2.0 ± 0.5 MV accompanies the reaction.

[1] Sampson, Ridenour and Bleakney, Phys. Rev. **50**, 382 (1936).

80. Transmutation-Processes of Li^6 and Li^7. L. H. Rumbaugh, *Bartol Research Foundation of the Franklin Institute,* R. B. Roberts and L. R. Hafstad, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—Thin targets of the separated isotopes of Li^6 and Li^7 have been used for the investigation of alpha-particle, proton, neutron, and beta-particle excitation-functions under deuteron bombardment for voltages between 200 and 1000 kv. Observations have been made on the voltage-dependence of the separation and relative intensity of the components of the proton doublet from Li^6. The excitation-curves show markedly different characteristics, dependent both upon the disintegration product and the parent nucleus.

81. The Transmutation of Aluminum by Polonium Alpha-Particles. W. R. Kanne, *The Johns Hopkins University.*—In order to resolve the conflicting results of Pose[1] and of Chadwick and Constable[2] the absorption curve of the protons emitted from a thick aluminum target has been repeated. The recording apparatus was an FP-54 vacuum tube electrometer. Alpha-particles from polonium deposited on silver were entirely absorbed in an aluminum foil. The protons emitted in this foil passed through calibrated mica foils into an ionization chamber. The angles subtended by the target and chamber were similar to those used in previous experiments. More than 50 points, of probable error between 3 percent and 10 percent, were obtained. The

eight groups described by Chadwick and Constable have been observed, and substantial agreement regarding ranges and yields confirms their results and interpretation. When the facts that the energy of the gamma-ray from the final $_{14}Si^{30}$ nucleus is 2.5 Mev, that the excitation energy of the intermediate $_{15}P^{31}$ nucleus is about 14.8 Mev, and that the ratio of the intensities of the short and long range groups is 3.5, are interpreted on the basis of the Bohr model of the nucleus, one finds that the statistical weight of the excited state of $_{14}Si^{30}$ must be three times that of the normal state. Since it is probable that the normal state has spin 0, this indicates that the excited state has a spin of 1.

[1] Zeits. f. Physik **95**, 84 (1935) and Zeits. f. Physik **75**, 753 (1932).
[2] Proc. Roy. Soc. **135**, 48 (1932).

82. Maximum Energy of the Protons Emitted by Boron under Alpha-Particle Bombardment. GORDON BRUBAKER AND ERNEST POLLARD, *Yale University.*—Accurate values for the masses of the light elements up to O^{16} are now known. These masses are in good accord with energies determined in transmutation with the exception of the reaction

$$B^{10}+He^4 \rightarrow C^{13}+H^1+3.3 \text{ Mev},$$

in which 4.5 Mev should be released. This reaction has been studied carefully by several workers and the yield of any longer range group than hitherto found must certainly be very small. It is of interest to determine whether any longer range group exists, since if it does not this would be an example of a transmutation in which radiation is associated with the most energetic group of emitted particles. We have therefore studied the absorption curve using an automatic recording arrangement. This registers the numbers of protons entering a counter and producing large and small ionization on two separate traces simultaneously. Our results indicate the presence of a very weak group of Q value 4.7 Mev ($\pm.5$) having a yield of about one thirtieth that of the group of Q value 3.3 Mev. Since this represents one thousandth of the total number of protons emitted it is clear that this transition is extremely improbable.

83. Accelerating Tube for the Round Hill Electrostatic Generator. C. M. VAN ATTA, R. J. VAN DE GRAAFF AND L. C. VAN ATTA, *Massachusetts Institute of Technology.*—A cascade[1] accelerating tube for use with the Round Hill electrostatic generator[2] has been built and tested. The tube rests on a 24-foot I-beam of Bakelite-impregnated plywood extending horizontally between the generator terminals and consists of four rigid 65-inch sections joined by flexible metal bellows. Each section has twelve porcelain cylinders and eleven steel electrodes, all clamped between heavy steel end plates by means of six plywood tension rods. The porcelain cylinders have external corrugations and are twelve inches in diameter. The electrodes consist of focusing cylinders three inches in diameter spaced with ½-inch gaps and held coaxially in the tube by diaphragms, the edges of which protrude slightly between the porcelain cylinders. Vacuum joints are made reliably tight by lead gaskets painted with Glyptal. The tube and I-beam are shielded against radial fields by seven rings consisting of tractor inner tubes coated with Aquadag and electrically connected to the tube at every sixth diaphragm. Voltage distribution is controlled by corona points attached to the edges of all diaphragms. The present tube, designed for half the generator voltage, reliably sustains its rated voltage of slightly over 2.5 megavolts and will be used for nuclear research while the parts are under construction for its extension to withstand the full voltage.

[1] W. D. Coolidge, J. Frank. Inst. **202**, 693 (1926); M. A. Tuve, G. Breit and L. R. Hafstad, Phys. Rev. **35**, 66 (1930).
[2] L. C. Van Atta, D. L. Northrup, C. M. Van Atta and R. J. Van de Graaff, Phys. Rev. **49**, 761 (1936).

84. Generating Voltmeter Measurements at Round Hill. D. L. NORTHRUP AND L. C. VAN ATTA, *Massachusetts Institute of Technology.*—There are certain requirements imposed upon an electrostatic generator and its housing by the necessity of making accurate generating voltmeter measurements. In particular, the capacity between the voltmeter and charged insulating surfaces should be made as small as possible by reducing these areas to a minimum and by properly locating the voltmeter. These requirements are satisfactorily met at Round Hill when a voltmeter is located in the top of each terminal. A generating voltmeter has been designed for this application with attention to all-over stability of calibration and convenience in use. A linear response on a short period d.c. output meter for a wide range of gradients (5 volts/cm to 10,000 volts/cm) is made possible by a 10-point range selector and a thermionic rectifier. Thus a calibrating voltage of 20 kilovolts is ample when measuring voltages up to 3 megavolts on one terminal. A discussion of technique will be given with special reference to the small corrections for the effect of insulator charge and interaction between terminals, necessary to obtain an accurate determination of total voltage.

85. Transmutation of Argon and Chlorine by Alpha-Particles. ERNEST POLLARD, H. L. SCHULTZ AND GORDON BRUBAKER, *Yale University.*—We have found the two elements argon and chlorine to emit neutrons when bombarded by alpha-particles from either RaC or ThC′. The yield from argon is larger than that from aluminum: that from chlorine is roughly one quarter as great. We suggest the following reactions take place:

$$A^{40}+He^4=Ca^{43}+n^1,$$
$$Cl^{37}+He^4=K^{40}+n^1.$$

In the second reaction the radioactive isotope of potassium is formed. Particular attention has been paid to the excitation curves. The first reaction gives a curve which follows the Gamow penetration formula for zero orbital angular momentum very closely if a nuclear radius of $7.6\pm.3\times10^{-13}$ cm is supposed for A^{40}. This fits with a radius of 13.6×10^{-13} cm for the radioactive nuclei and agrees with Bethe's recent value of 13.0×10^{-13} cm. Applying the conservation of angular momentum the spin of Ca^{43} should differ from that of A^{40} by ½. The chlorine reaction is more uncertain because of the smaller yield but there are indications that the expected nuclear radius cannot explain the results unless the incident alpha-particle has an orbital angular momentum $1=1$ or $1=2$. This implies that K^{40} has a spin of 3 or greater. This would

account for the abnormally great lifetime of K^{40}, for a transition to Ca^{40} would require a considerable change in angular momentum.

86. The Photodisintegration of the Deuteron. J. REGINALD RICHARDSON AND LORENZO EMO, *University of California.*—The photodisintegration of the deuteron by the gamma-radiation from radioactive sodium, Na^{24}, has been observed in a cloud chamber. The cloud chamber contained deuterium at a pressure slightly above one atmosphere. A sample of NaF was activated by deuteron bombardment in the cyclotron to a γ-ray strength equivalent to about 12 mg of radium, and was then brought close to the cloud chamber. Pictures were taken with a stereoscopic camera. Preliminary results on about 4000 pictures show a total of 42 measurable tracks. The range distribution of these tracks indicates a mean air equivalent range of about 4.5 mm. This corresponds to a mean energy of 300 kv for the photo protons, or, assuming the binding energy of the deuteron at 2.2 MV, it indicates that the energy of the most energetic Na^{24} gamma-ray is 2.8 MV. The angular distribution of the tracks indicates that the disintegration is predominantly photoelectric, although a small contribution from the photomagnetic effect is not ruled out. A rough calculation from the yield of tracks, knowing the sensitive time of the cloud chamber, indicates a cross section of about 1×10^{-27} cm². It is our opinion that this method is capable of considerable accuracy in the determination of the energy of gamma-radiation from strong sources when the energy is above 2.2 MV.

FRIDAY AFTERNOON AT 2:00 O'CLOCK

National Bureau of Standards

Chemistry Building, Lecture Room

87. The Damping of Torsional Oscillations in Quartz Fibers. G. A. DOWNSBROUGH,* *Rutgers University, New Brunswick, N. J.*—The results obtained by previous workers have been qualitatively confirmed, but it was demonstrated that many of the perplexing features were characteristic of the material used to mount the quartz fibers, and not of the fibers themselves. When fused quartz joints were substituted, these features were eliminated, and in addition the damping became very much smaller than in any previous work. As a result, it was also necessary to investigate energy losses hitherto unimportant; several were found capable of affecting the results, but in the final arrangement they were all insignificant. On the assumption that the damping is a purely viscous phenomenon, it is shown that the product of the period of oscillation and the logarithmic decrement should be a constant of the material. This was experimentally verified over a small range of periods; the value obtained was 1.3×10^{-5}. The coefficient of viscosity for quartz, derived from this, is 2.2×10^{5} g/cm sec.

* Now with the Research Laboratories of Johns-Manville Corporation, Manville, N. J.

88. The Mechanism of Internal Friction. CLARENCE ZENER, *Washington University.*—The concept of internal friction has been introduced many years ago to explain the gradual damping of vibrations in solids. The mechanism of internal friction has nevertheless remained obscure. In this paper such a mechanism is discussed from a theoretical viewpoint, and experiments are suggested whereby this mechanism can be tested. The theory of internal friction here discussed is obtained by considering solely the thermodynamical aspects of vibrations. If the vibrations were adiabatic, strain would be a linear function of stress. Similarly, if the vibrations were isothermal, strain would also be a linear function of stress. When, however, the vibrations are neither adiabatic nor isothermal, the relation between stress and strain is represented by a closed hysteresis curve. This hybrid type of vibration is obtained in the transverse vibrations of thin reeds. The area of the hysteresis loops has been exactly calculated for such reeds. The value of the logarithmic decrement thus obtained is of the same order of magnitude as the experimental values (which disagree from each other by several hundred percent), its precise value depending upon the frequency of vibration, the thickness of the reed, and its temperature.

89. The Elastic Constants of Crystalline Sodium at 80°K. SIDNEY SIEGEL, *Columbia University.*—The elastic constants of crystalline sodium at 80°K have been measured by the composite piezoelectric oscillator method of Balamuth and Rose.[1] The sodium is made by heating C.P. NaCl with metallic Ca. Single crystal cylinders 4.8 mm in diameter and 7 cm or less long are grown in vacuum in oiled glass crucibles by Bridgman's method. The experimental method yields the value of Young's modulus and the torsion modulus for the direction of the cylinder axis. The direction cosines of this axis with respect to the principal axes of the crystal are obtained from a series of Laue photographs, taken with the x-ray beam normal to the cylinder axis. The principal elastic constants are calculated with the formulae which relate these quantities to the observed Young's and torsion moduli. Observations are reported on three crystals whose axes lie approximately in the 100, 110 and 111 directions in the lattice. The values of the constants are, $s_{11}=5.02\pm.05$, $s_{12}=-1.78\pm.04$, $s_{44}=0.81\pm.04$, all times 10^{-11} cm²/dynes. These may be compared with the theoretical values calculated by Fuchs,[2] namely, $s_{11}=4.86$, $s_{12}=-2.24$, $s_{44}=1.72$, all times 10^{-11}. It is intended to extend these measurements to potassium and lithium, and to investigate the variation of the constants with temperature at low temperatures.

[1] Balamuth, Phys. Rev. **45**, 715 (1934); Rose, Phys. Rev. **49**, 50 (1936).
[2] Fuchs, Proc. Roy. Soc. **157**, 444 (1937).

90. The Estimation of Intergranular Surfaces and Volumes in Metals. HERMAN F. KAISER, *Naval Research Laboratory, Washington, D. C.*—In many instances the intergranular surfaces of separation in metals suggest an almost regular geometrical structure. For such cases it is possible to carry out an approximate treatment by visualizing the metal as built up of regular space-filling parallelohedra. In this paper expressions are derived, using the four parallelohedra of Fedorov, for the internal surface, the intergranular volume and the density of the model metal as functions of the grain size and composition of the metal. Results are applied to the computation of amounts of totally insoluble impurities required to produce grain envelopes of given thickness. The bearing on Tamman's theory of recrystallization is discussed.

91. The Formation of Metallic Bridges in Separated Contacts. G. L. PEARSON, *Bell Telephone Laboratories, Inc.*—Low resistance bridges were formed between gold, steel and carbon electrodes having separations of $2\text{–}70\times10^{-8}$ cm by applying voltages less than the minimum sparking potential. For a given pair of electrodes the field required to form the bridges is a constant and is $5\text{–}16\times10^{6}$ volts per centimeter. Measurements of the temperature coefficient of resistance of the bridges identify them as consisting of the material of the electrodes. A study of their resistance as a function of the displacement of one of the electrodes shows that they may be pulled out as well as crushed. At voltages less than those required to form the bridges, field currents exist. These increase rapidly as the field is raised and attain a value around 10^{-10} ampere before the bridges are formed. Calculation of the maximum electrostatic stress on the electrodes at the time of breakdown gives a value 0.05 to 0.0005 times the tensile strength of the electrode material at room temperature. The field is locally higher than that calculated because of surface roughness and the tensile strength is probably lowered by the local heating known to accompany field currents. The data therefore indicate that electrostatic force pulls material from the electrodes to bridge the gap.

92. Diffusion of Hydrogen through Iron at Temperatures between 780° and 90°C. W. L. RAST AND W. R. HAM, *Pennsylvania State College.*—Measurements in the temperature range 780° to 90°C of the rates of diffusion of hydrogen through different samples of highly decarburized carbonyl iron indicate abrupt changes in slope of log (Rate) *vs.* $1/T$°K graphs at the following temperatures: 767, 729, and in the region of 200°C. As previously observed by Ham,* the log (Rate) *vs.* $1/T$°K graph is found to be nonlinear in the Curie region extending from 767° to 729°C. Between 729° and approximately 200°C the graph is nearly linear, and the value of the constant b in the empirical equation $R=Ae-b/T$ (where R represents rate of diffusion, T the absolute temperature, A and b constants) is 4200, about the value found by most other observers. However, around 200°C an abrupt decrease in the rate of diffusion occurs, the rate falling to one-hundredth of its value in an interval of about 30 degrees. Below this discontinuity the decrease of the rate with decrease in temperature to 90°C is very small, the value of "b" being approximately 1000. For each sample investigated a considerable hysteresis is noted in the vicinity of the 200°C discontinuity.

* "The Diffusion of Hydrogen through Nickel and Iron," by W. R. Ham, in process of publication in the Trans. Am. Soc. Metals.

93. The Diffusion of Hydrogen through Carbonyl Iron at Temperatures from 900° to 1125° Centigrade. C. B. POST AND W. R. HAM, *Pennsylvania State College.*—The diffusion of hydrogen through hydrogen-purified Mehl-Iron shows breaks in the log (Rate) *vs.* $1/T$ curves at 909°C (Body-Centered→Face-Centered phase change), 952, 1012, 1057, 1082, 1103 degrees centigrade. The experimental procedure at these high temperatures is difficult and the experimental technique is being improved, so that the above values from 1050° upwards are subject to revision. The curves of log R *vs.* $1/T$ are found to be straight segments of curves satisfying a relation, log $R=A-b/T$, the segments being clearly differentiated from one another at the above temperatures.

94. The Change from γ-FeOOH and γ-Fe_2O_3 to α-Fe_2O_3 at Lower Temperatures and the Irreversible Transition: γ-FeOOH to α-FeOOH. LARS A. WELO, *Tottenville, Staten Island, New York* AND OSKAR BAUDISCH, *Saratoga Springs Authority, Saratoga Springs, New York.*[1]—In open containers γ-FeOOH dehydrates in an hour at 250°C, yielding ferromagnetic γ-Fe_2O_3. At 400°C this oxide, in turn, changes irreversibly to paramagnetic α-Fe_2O_3 in an hour. In sealed tubes, along with sufficient water for saturation, the overall change occurs in an hour at 136°C but intermediate γ-Fe_2O_3 does not appear. γ-Fe_2O_3 also changes in this "wet" way to α-Fe_2O_3 at the same temperature and rate as its parent hydrate. We infer the occurrence of the irreversible transition γ-FeOOH to α-FeOOH and that α-Fe_2O_3 is shed to satisfy the equilibrium requirements of the system α-FeOOH, α-Fe_2O_3 and water. If we start with γ-Fe_2O_3, transition is preceded by hydration of γ-Fe_2O_3 to γ-FeOOH. But this hydrate disappears by transition so that the reaction goes forward until all γ-Fe_2O_3 is consumed. Similar depression of the transformation temperature occurs in γ-Fe_2O_3 made by oxidation of precipitated magnetite and our observations support the generalization that when γ-Fe_2O_3 is stabilized against the irreversible transition to α-Fe_2O_3, this stabilization persists with respect to the transition between the corresponding hydrates.

[1] For the most part, this work was done in the Research Laboratory of the Consolidated Gas, Electric Light and Power Company of Baltimore.

95. Reciprocals to Ampere's Law. PRESTON B. CARWILE, *Lehigh University.*—Consider Ampere's law as expressed (in the *em* system) by the familiar vector equation (1) $d\mathbf{H}=id\mathbf{s}\times\mathbf{r}/r^3$. If we generalize this equation to include displacement current, then apply the well known principle of reciprocity between corresponding electric and magnetic entities and finally drop the term for magnetic convection current (since, as yet, we have no experimental evidence for the existence of free magnetic poles), we obtain (2) $d\mathbf{E}=-\dot{\Phi}d\mathbf{s}\times\mathbf{r}/4\pi r^3$, where $\dot{\Phi}$ is the time rate of change of

total flux in a magnetic circuit. Eq. (2) is the effective reciprocal to Eq. (1). Or Eq. (2) may be regarded as a variant form of Faraday's law of electromagnetic induction. Again, starting with Ampere's law of the equivalence of an electric current i to a simple magnetic shell of strength ρ given by (3) $\rho=\mu i$, we obtain, by a similar application of reciprocity, the law of equivalence of a magnetic circuit in which flux is changing at the rate $\dot{\Phi}$ to a simple electric shell having the magnetic circuit as its boundary and having the strength (electric moment per unit area) given by (4) $\sigma=k\dot{\Phi}/4\pi$, where k is the dielectric constant. Eqs. (2) and (4) involve no new principle. Their explicit forms are believed to be new. They find ready use in an elementary treatment of magnetoelectric fields.

Friday Afternoon at 2:00 o'clock

National Bureau of Standards

Industrial Building, Room 301

96. A New Recording Microphotometer.* H. V. Knorr and V. M. Albers, *Antioch College.*—A new microphotometer has been constructed, using an emission type photocell as the light sensitive device and a Leeds and Northrup Speedomax Recorder. The photographic plate and the recording paper are moved by synchronous motors operated from the same a.c. source. An inked curve is traced by a pen, whose motion can be observed during the recording. An amplifier, using type 40 tubes in a balanced tube circuit, is employed to amplify the photoelectric current. The speed of the recording paper is fixed at 5 cm per minute. The relative speeds of the plate and recorder can be varied by means of a system of reducing gears mounted on the plate carriage. The plate holder is mounted to the plate carriage in the same manner as the plate holder in an ordinary camera. A drum is rotated through a gear system by a synchronous motor and pulls the plate carriage along a track by means of a steel ribbon. The sensitivity of the recorder can be varied from 2.5 to 8 millivolts for a full scale deflection of 25 cm. This microphotometer is very stable and is not affected by mechanical vibrations. The zero of the instrument is very constant.

* The present paper will appear in full in R. S. I.

97. The Effects of Elastic Stretch on the Infrared Spectrum of Rubber. Dudley Williams and Richard Taschek, *University of Florida.*—The absorption spectrum of stretched rubber has been studied in the region between 2μ and 8μ. In the case of unilateral stretch transmission measurements indicate that the absorption bands near 3.25μ and 7μ become broader with increasing stretch while the background absorption becomes more pronounced. Radial stretch was found to produce similar effects in the 3.25μ and 7μ regions. The bands appearing near 6μ become less intense in the case of radial stretch. In the spectra of a number of samples which had been stretched radially a new band appeared near 4.8μ. Since both absorption and reflection are involved in transmission measurements, it was found necessary to determine both reflection and extinction coefficients. The results indicate that the reflection coefficient diminishes and the extinction coefficient increases with increasing stretch. The observed variations in the extinction coefficients are considerably larger than those arising from the known density changes which accompany stretching.

98. The Infrared Absorption of Aqueous Solutions of the Halogen Salts. E. K. Plyler and E. S. Barr, *University of North Carolina and Tulane University.*—The infrared absorption spectra of the aqueous solutions of NaCl, NH_4Br, KF, NH_4F and KI have been measured in the region from 3μ to 6.5μ. The concentrations of the solutions were varied from 1 N to 6 N. Some modification of the 3μ and 6.2μ water bands was noticed. The water band at 4.7μ, however, showed a shift in position which was always of the same amount when the negative ion in the solution was the same. All solutions containing fluorine had the maximum intensity at about 4.65μ. The chlorine shifted the band to 4.78μ, bromine to 4.8μ, and iodine to 4.9μ. The actual position of the band varied somewhat with the concentration. This effect was thought to be due to the varying amount of water present, and the overlapping of the 4.7μ absorption band in this region. It is difficult to state whether these bands are produced by the association of the negative ions, or if a shift is just produced in the water band itself. A number of other substances did not produce the corresponding effect on the 4.7μ water band.

99. The Infrared Absorption Spectrum of Formic Acid Vapor. Lyman G. Bonner* and Robert Hofstadter, *Princeton University.*—The spectrum of formic acid vapor has been measured in the region 1–15.5μ and at several temperatures between 25° and 140°C, using a rocksalt prism spectrometer. Since formic acid exists principally as double molecules at 25° and is largely dissociated at 140° this procedure has made it possible to separate the spectra of the dimer and monomer. The dimer shows strong absorption bands at 3080, 2530, 2380, 1905, 1740, 1350, 1205, 1090, 917 and 667 cm^{-1} while the monomer absorbs only at 3550, 2940, 2325, 1740, 1090 and 658 cm^{-1}. Using the method of rigid groups, force constants for the C−O and C=O bonds of the monomer have been calculated, the values being 5.4 and 11.8×10^5 dynes/cm respectively. Since the normal value for C−O is nearer 4.5×10^5 the above figure would indicate the existence of a certain amount of single-double bond resonance in this molecule, as postulated by Pauling and Sherman.[1]

* National Research Fellow.
[1] J. Chem. Phys. 1, 606 (1933).

100. Photographic Penetration of Haze. NORA M. MOHLER, *Smith College.*—Photographs have been taken from Mt. Nonotuck in the Connecticut valley, with plates and filters registering from 0.4 to 1.0μ, in steps of about 0.1μ. Visibilities varied from less than 3 miles to more than 50, weather conditions from thick haze and fine rain to very clear. The photographic "visibility" has been plotted against wave-length, and the curves compared with the theoretical curve given by Stratton and Houghton[1] and Hulburt.[2] The position of maxima and the change in slope of the curves make possible an estimate of the size of some drops by this comparison; typical results are: thick haze, visibility 3 miles, drops of radius 1.3μ and much larger; fine rain, visibility 6.5 miles, r is 1.1 with others less than 0.8 as well as some much larger; thin haze, visibility 12 miles, r is 1.1 and less than 0.7; extremely clear, r is less than 0.22μ.

[1] Phys. Rev. **38**, 159 (1931).
[2] J. O. S. A. **25**, 125 (1935).

101. Optical Properties of Evaporated Films. D. H. ANDREWS, J. A. SANDERSON AND E. O. HULBURT, *Naval Research Laboratory.*—In the spectrum region from 0.185 to 10μ the reflectivity and transmission have been measured of films of Al, Sb, Be, B, Cr, Mg, Mn, Si and Te prepared by evaporation in vacuum. The reflectivities agreed in the main with previous measurements in as far as these exist. Minima of reflection in the infrared were noted for Sb, B, Si and Te which appeared to be due to interference, as evidenced by the spacing of the minima and their shift with film thickness.

102. The Scattering of Light by Water. L. H. DAWSON AND E. O. HULBURT, *Naval Research Laboratory.*—By means of a quartz spectrograph and a densitometer the relative intensity of light scattered by pure water was measured throughout the spectral region from 5461 to 2536A. The scattering coefficient was found to increase with decreasing wave-length in fair agreement with the $\lambda^{-4}f(\mu)$ expression derived from the density fluctuation theory of Einstein and Smoluchowski.

103. The Visible Absorption Spectra of Porphin and Its Isomer. V. M. ALBERS AND H. V. KNORR, *Antioch College.*—All porphyrins are characterized by a ring system composed of four pyrrole rings joined by carbon atoms between them. The simplest possible porphyrin is porphin, synthesized by Rothemund[1] in 1935. Rothemund obtained two substances with porphyrin properties which differ in hydrochloric acid number and which have been demonstrated to be isomers. This is the first case of isomerism observed for porphyrins. The substance having the larger hydrochloric acid number (3.3) has been named porphin and the one with the smaller hydrochloric acid number (0.5) has been named *iso* porphin. The absorption spectra of porphin and some of the *ms* substituted porphins have been reported by Albers and Knorr.[2] The absorption spectrum of *iso* porphin has been measured in the visible region. The general pattern is similar to that of porphin except for a shift in wave-length of the bands about 100A toward the red. The most pronounced difference in the spectra, however, is in the values of the absorption coefficients. The absorption coefficients in the bands are about three times as large for porphin as they are for *iso* porphin.

[1] Paul Rothemund, J. Am. Chem. Soc. **57**, 2010 (1935).
[2] V. M. Albers and H. V. Knorr, J. Chem. Phys. **4**, 422–425 (1936).

104. Energy Levels in Neon and Argon. J. B. SAMPSON, *Allegheny College. (Introduced by C. W. Ufford.)*—The energy levels in intermediate coupling for the neon $2p^5 3d$ and argon $3p^5 5d$ configurations were calculated. Shortley has already done so for several configurations of neon by neglecting the electrostatic interaction between groups having $^2P_{\frac{1}{2}}$ and $^2P_{3/2}$ as parents. The configurations treated here are the only two for which experimental results are completely available, and to which Shortley's approximation does not satisfactorily apply. The 6 radial integral parameters were found approximately from the available linear equations and were then adjusted by the process of least squares to fit all the observed values as well as possible. For neon the agreement with all the observed levels was to within 1 wave number in a spread of 900.

105. The First Spark Spectrum of Platinum. A. G. SHENSTONE, *Princeton University.*—The low multiplets of Pt II are mainly in the Schumann region. To obtain the lines in a source producing low excitation, arcs and sparks were run in pure nitrogen, the source being placed so as to be focussed on the slit of a vacuum spectrograph by a fluorite lens which formed the vacuum seal of the spectrograph. The nearly stigmatic images made the separation of stages of ionization very simple. The analysis has so far yielded the even levels given below. About 40 odd levels have been found. The wave number difference is approximately 155800 from $5d^9\,{}^2D_{2\frac{1}{2}}$ to $5d^8\,{}^3F_4$.

Even Levels of Pt II

Level	J	Probable Origin	Level	J	Probable Origin
−4786.4	$2\frac{1}{2}$	$d^9\,{}^2D_{2\frac{1}{2}}$	16931.0	$\frac{1}{2}$	d^8s
0.0	$4\frac{1}{2}$	$d^8s\,{}^4F$	18675.1	$2\frac{1}{2}$	$d^8s\,{}^2F$
3633.4	$1\frac{1}{2}$	$d^9\,{}^2D_{1\frac{1}{2}}$	19089.4	$1\frac{1}{2}$	d^8s
4569.6	$3\frac{1}{2}$	$d^8s\,{}^4F$	20093.3	$4\frac{1}{2}$	$d^7s^2\,{}^4F$
8542.7	$2\frac{1}{2}$	$d^8s\,{}^4F$	22469.5	$\frac{1}{2}$	d^8s
11004.9	$1\frac{1}{2}$	$d^8s\,{}^4F$	29861.1	$3\frac{1}{2}$	$d^7s^2\,{}^4F$
12034.4	$2\frac{1}{2}$	$d^8s\,{}^2D$	33091.5	$\frac{1}{2}$	$d^8s\,{}^2S$
13311.3	$3\frac{1}{2}$	$d^8s\,{}^2F$	91014.4	$4\frac{1}{2}$	d^87s
16382.4	$1\frac{1}{2}$	d^8s	91825.5	$3\frac{1}{2}$	d^87s

106. The First Spark Spectrum of Manganese. C. W. CURTIS, *Western Reserve University.*—The analysis of the Mn II spectrum has been extended to include a classification of over five hundred lines. From four members of the $3d^5(^6S)nf\,{}^7F$ series an ionization potential of 126,147 wave numbers has been calculated by means of a Ritz formula. Pictures have been taken and measurements made covering the range from approximately 800A to 6000A. A hollow cathode discharge was used as a source, with each of the three gases, helium, argon and neon, as conducting media.

107. Interference Measurements in the Spectra of the Noble Gases in the Ultraviolet. C. J. HUMPHREYS, *National Bureau of Standards.*—Wave-length measurements in the first spectra of the noble gases, in the ultraviolet to 3369A, have been made, using F–P interferometers with alumi-

nized quartz plates and étalons of 3, 7.5, 15, 20 and 25 mm length. The wave-lengths have been determined relative to the adopted International Standards in Kr I and Ne I. All but three of the thirty possible $1s$–$3p$ lines of Ne I are intense enough to permit interference measurements. Measurements in Kr I comprise 28 lines of shorter wave-length than λ4274, the limit of previous work. It is now possible to fix the various p-series of Kr I to four members by interference methods. Some extensions have also been made in A I and Xe I. The short wave-length limit to these measurements is set by the intensity decrement of lines approaching the series limits, the $1s$-levels (^1P, ^3P) of the noble gas spectra. It is expected that the more intense lines will prove useful as wave-length standards. The neon group is the most promising in this respect. The possibility of a pressure effect in higher series lines is being investigated by comparing wave-lengths obtained with Geissler tubes filled with "low" and "high" gas pressures. A series of measurements of A II comprising about 150 lines has also been carried out.

108. The Coupling of the Normal p-Electron Configurations. H. A. ROBINSON AND G. H. SHORTLEY, *Ohio State University.*—The application of the intermediate coupling theory has been considered in detail for the configurations p^2, p^3 and p^4 in the long isoelectronic sequences which have been recently analyzed. Curves have been plotted giving the ratios of various intervals in these configurations as a function of the single parameter which specifies the type of coupling. If the parameter be determined from an experimental value of one of these ratios, the other ratios may be predicted. In half the cases the agreement of the predicted values with experiment is very good; for the others the departure is sufficiently regular to permit accurate prediction of unknown terms. This, in at least one case, has led to definite classification of a new level. Of particular interest is the very rapid departure of the Landé interval ratio from its Russell-Saunders value, which explains most of the anomalous observed Landé ratios in these configurations. These considerations permit evaluation of the energy parameters occurring in the theoretical formulas. The electrostatic interaction parameter F_2 is a linear function of Z to a good approximation; the spin orbit parameter ζ varies as $(Z-S)^4$; their ratio, the coupling parameter, varies as $(Z-S)^3$. These are in accordance with the theoretical expectations.

SATURDAY MORNING AT 9:30 O'CLOCK

George Washington University

Corcoran Hall, Room 29

109. A Pyrheliometer Having a Spherical Absorber is Used to Follow Sunspot Activities. L. F. MILLER, *University of Minnesota.*—A pyrheliometer employing a very thin blackened spherical absorber[1] enclosed in a highly evacuated quartz bulb was used to measure the solar radiations emitted during the passing of a group of sunspots during the first months of 1936 and the group now in progress since about August of this same year. This instrument has a geometrical, optical and thermal symmetry which gives it the same sensitivity for all positions of the sun. It may be known as the total intensity method for measuring sunspot activities. Other methods of following these sunspot activities are by the magnetic effect, the ultraviolet light, the variation of the solar constant, radio fading and by photographing the sunspots directly. From the latter are determined Wolf numbers which at present are accepted as the best index of these activities. Curves may be plotted for each of these different methods with the day as the abscissae unit and the ordinate as the measure of the effect observed. Ten day smoothed curves were made in each case. Using these smoothed curves, scatter diagrams and correlation coefficients were determined between the Wolf number curve and each of the other curves. A correlation coefficient of 0.5 has been obtained for the total intensity method and 0.435 for the magnetic effect as the next best value. Observations with two carefully coordinated instruments and a sun shield are being conducted over a period of six months to a year to obtain certain corrections for the total intensity values which should not alter the general synchronism between its curve and that of the Wolf numbers and should improve the correlation.

[1] Miller, Rev. Sci. Inst. **5**, 405 (1934).

110. The Spectrum of Caesium Hydride. M. P. RASSWEILER AND G. M. ALMY, *University of Illinois.*—A band system of CsH has been photographed in absorption with a 3-meter glass prism spectrograph having a dispersion of some 5A per mm. The absorption column was obtained by heating metallic caesium in a steel tube under hydrogen at atmospheric pressure. The center of the tube was heated to about 600°C, the ends being cooled to protect the windows. The spectrum is of the many line type and extends from 4500A to 6250A. About 90 percent of the observed lines have been assigned to 30 two-branch bands, falling in 3 v' progressions. The vibrational and rotational analysis and the calculation of constants have been completed, except that there remains an additive uncertainty in the v' numbering, due to the covering of the red end of the system by a Cs_2 system. The upper state shows the same anomalous behavior of B and ΔG as has been previously reported in the corresponding $^1\Sigma-{}^1\Sigma$ systems of LiH, NaH and KH.

111. Band Spectra of NiCl and CoCl. KENNETH R. MORE,* *Yale University.*—Band spectra attributed to the NiCl and CoCl molecules have been excited by a h.f. discharge in a quartz tube containing $NiCl_2$ and $CoCl_2$, respectively, in the two cases. The tube was heated externally in order to maintain the discharge. The bands were photographed with a grating having a dispersion of 2.5A per mm. The NiCl bands, which extend from 3900 to 4700A, show several prominent heads degrading to longer wave-lengths. A vibrational analysis shows that the bands can be arranged into four systems with the following constants, in cm^{-1}:

	$\sqrt{\nu_0}$	ω_e'	$\chi_e'\omega_e'$	ω_e''	$\chi_e''\omega_e''$
A_1	24623.8	402.9	1.6	420.4	1.1
A_2	24138.0	402.9	1.6	419.1	1.1
A_3	23233.2	399.6	1.7	420.4	1.1
A_4	22748.4	399.6	1.7	419.1	1.1

The vibrational constants indicate that A_1 and A_2 have a common upper state, as have A_3 and A_4. In addition A_1 and A_3 have a common lower state, as have A_2 and A_4. The electronic interval of 485 cm^{-1} between A_1 and A_2 and between A_3 and A_4 is attributed to the ground state. This is a reasonable electronic doublet splitting considering the A factors of the ground states of Ni I and Cl I. The CoCl bands fall in the region 4300 to 4900A and degrade to the red. The FeCl spectrum also is being investigated.

* Sterling Fellow.

112. Ultraviolet Bands of Magnesium Hydride. LOUIS A. TURNER AND W. T. HARRIS, *Princeton University.*—Plates were obtained with a Hilger E-1 quartz spectrograph. They show all of the structure of the bands of the 2430 system which have been measured by Pearse and by Guntsch. In addition they show the structure of a Q branch of the 1–0 band. The expected P and R branches of the 0–1 band, hitherto unobserved, are well developed. They break off sharply as in the 0–0 band. The most surprising result is the appearance of many lines of P and R branches of the 1–2 band. Such branches are missing from the 1–1 band. If the accepted theory of predissociation in the $v'=1$ levels be correct they should not appear in the 1–2 band. The explanation of this result is yet to be found. A few lines near the head of the Q branch of the 2–2 band appear.

113. The Spectra of Scandium IV and Scandium V and Their Relation to the Spectra of the Isoelectronic Sequences Starting with Argon and Chlorine. L. W. PHILLIPS AND P. GERALD KRUGER, *University of Illinois.*—The successful excitation of the spectra of scandium in a hot spark has made it possible to identify multiplets arising from electron transitions to the ground states of Sc IV and Sc V. With the help of displaced frequency diagrams, it has been possible to identify corresponding multiplets in Ca IV. The terms identified and corresponding transitions are given in Tables I and II.

TABLE I. *Scandium IV. Argon sequence.*

	$3p^4 4s$		$3p^5 5s$	
	$^3P_1$	$^1P_1$	$^3P_1$	$^1P_1$
Sc IV $3p^6\,^1S_0$	(3) 335,540	(4) 340,994	(15) 460,432	(1) 464,432

TABLE II. *Ca IV and Sc V. Chlorine sequence.*

	Calcium IV		Scandium V	
	$3s^2 3p^5$		$3s^2 3p^5$	
	$^2P^0_{3/2}$	$^2P^0_{1/2}$	$^2P^0_{3/2}$	$^2P^0_{1/2}$
$3s3p^6\,^2S_{1/2}$	(12) 152,440	(10) 149,316	(8) 174,419	(7) 170,084
$3s^2 3p^4 4s(^3P)^2P_{3/2}$	(25) 298,175	(5) 295,047	(15) 395,496	(3) 391,166
$3s^2 3p^4 4s(^3P)^2P_{1/2}$	(1) 300,249	(15) 297,128	(7) 398,437	(10) 394,107
$3s^2 3p^4 4s(^1D)^2D_{5/2}$	(15) 314,373		(12) 410,043	
$3s^2 3p^4 4s(^1D)^2D_{3/2}$	(4) 314,078	(10) 310,952	(1) 410,114	(11) 405,786
$3s^2 3p^4 4s(^1S)^2S_{1/2}$	(5) 337,207	(4) 334,096	(2) 437,503	(2) 433,178

* Identified by Bowen. Phys. Rev. **31**, 498 (1928).

Graphs showing the relation of these spectra to the spectra of other ions in the sequence will be shown.

114. The Spectra of Scandium VI and Scandium VII and Their Relation to the Isoelectronic Sequences Starting with Sulphur and Phosphorus. H. S. PATTIN AND P. GERALD KRUGER, *University of Illinois.*—The spectra of scandium have been photographed in the wave-length region $\lambda=80$A to $\lambda=700$A. Multiplets involving radiation from electron transitions to deep terms have been identified in Sc VI and Sc VII. These are given in Table I and Table II, respectively.

TABLE I.

$3s^2 3p^4$	$^3P_2$	$^3P_1$	$^3P_0$	$^1D_2$	$^1S_0$
Term Values	0	3350	4476	21,397	49,238
$3s^2 3p^3 4s$					
$(^4S)\,^5S_1^0$	(30) 452,073	(6) 448,722	(2) 447,590		
$(^2D)\,^3D_2^0$	(0) 472,375	(4) 469,056	(5) 467,930		
$^3D_2^0$	(5) 472,553	(8) 469,210			
$^3D_3^0$	(15) 472,985				
$(^2D)\,^1D_2^0$	(1) 478,354	(1) 474,991		(15) 456,955	
$(^2P)\,^3P_0^0$		(5) 488,460			
$^3P_1^0$	(2) 492,092	(2) 488,750	(5) 487,646		
$^3P_2^0$	(6) 492,800	(8) 489,452		(1) 471,405	
$(^2P)\,^1P_1^0$	(1) 497,983		(0) 493,491	(8) 476,585	(3) 448,744

TABLE II.

$3s^2 3p^2 4s$	$(^3P)\,^4P_{1/2}$	$^4P_{3/2}$	$^4P_{5/2}$	
$3s^2 3P^0$				
$^4S^0_{3/2}$	(7) 541,691	(543,650)	(12) 546,469	
	$(^3P)\,^2P_{1/2}$	$^2P_{3/2}$	$(^1D)\,^2D_{5/2}$	$^2D_{3/2}$
$^2D^0_{3/2}$	(8) 521,916	(525,192)	(1) 538,866	(7) 539,008
$^2D^0_{5/2}$		(8) 524,511	(10) 538,190	
$^2P^0_{1/2}$	(2) 502,101	(1) 505,380		(8) 519,192
$^2P^0_{3/2}$	(1) 501,193	(5) 504,467	(15) 518,135	(518,282)

115. An Extension of the Yt I and Yt II Spectra. I-DJEN HO AND R. A. SAWYER, *University of Michigan.*—The yttrium spectrum has been photographed from a hollow cathode discharge, with a concave grating vacuum spectrograph and with quartz and glass prism spectrographs. A total of 540 yttrium lines were identified in the region from λ5700 to λ780. Sixty-five new lines were found to be combinations of previously established Yt I and Yt II energy levels. The classification of 247 new lines fixed the position of 38 new Yt II levels which cover the range from 11,724.3 to 129,251.0 ν units. With the available data, the empirical analysis indicates that the Yt II energy scheme does not resemble that of the isoelectronic spectrum, Sr I,

which has the series of $5s\ nX$ configurations well developed. The higher states of $4d\ nX$ and $5p\ nX$ of singly ionized yttrium atom are also excited. The closeness of the higher levels of same parity but of different configurations results in strong perturbations which destroy the appearance of multiplets and series among these levels and make their assignment difficult.

116. Term Values in Carbon. C. W. Ufford, *Allegheny College.*—The energies of the terms of the normal state of CI, $1s^2 2s^2 2p^2$, and the excited state, $1s^2 2s 2p^3$, have been calculated using Torrance's values of the one-electron Hartree functions. This involved the numerical integration of 25 Slater integrals, from which the terms could then be found by his method. In this way the energy for the normal state is -37.6187 atomic units plus the contribution of $F^2(2p, 2p) = 0.2134$ giving the different terms. The lowest $^3P = -37.6614$. For the excited state $^1P = -37.1439$, and the separations of the other terms depend only on $F^2(2p, 2p) \equiv 0.2197$ and $G^1(2s, 2p) = 0.3217$. Fried, working with Shortley, has found $F^2(2p, 2p) = 0.2137$ independently for the ground state by solving the differential equations. This agrees well with the value above, considering the different method used. The separations do not agree well with the observed values. This was to be expected, since the theoretical ratio of the singlet to the singlet-triplet separation is 1.5 in the normal state, whereas the experimental value is 1.13. The separations are somewhat closer to the calculated values of Bacher and Goudsmit.

117. Multiplet Intensities from Electric Furnace Absorption Spectra of Fe I and Ti I. Robert B. King, *Massachusetts Institute of Technology* and Arthur S. King, *Mt. Wilson Observatory.*—The *total absorptions* of the lines of Fe I and Ti I in electric furnace absorption spectra have been measured and the relative intensities of the lines arising from different low levels derived from the *linear* portion of the *curve of growth* of an absorption line. The condition of thermal equilibrium at a known temperature in the furnace allows the observed intensities to be corrected for a Boltzmann distribution of the atoms among the different low energy levels from which they arise. The absorption spectra method is limited to lines arising from the lower energy levels in the atoms (low E.P. of 0.0 to 2.0 volts). The intensities of 145 lines in 22 multiplets of Fe I, in addition to those previously published,[1] and of 229 lines in 48 multiplets of Ti I. The lines lie between λλ2900–5500 for Fe and λλ3100–6700 for Ti. A comparison of the results with the solar intensities of many of these lines measured by Allen[2] permits a new determination of the temperature of the solar reversing layer.

[1] Astrophys. Jour. **82**, 377 (1935).
[2] Mem. Commonwealth Solar Observatory, Canberra, Australia, No. 5.

118. The Zeeman Effect in Neon. J. B. Green and J. A. Peoples, Jr., *Ohio State University.*—Back has studied the Zeeman effect in neon and has measured the g-values of the $2p^5 3s$ and the $2p^5 3p$ configurations. Using a very powerful electrodeless discharge in pure neon gas in a small capillary between the poles of an electromagnet in a field of 28,000 gauss we have observed and measured the g-values of the $2p^5 4p$ and $2p^5 3d$ and $2p^5 4d$ configurations. Our measurements are in excellent agreement with Back's measurements on the $2p^5 3s$ configuration. The $2p^5 4p$ g-values are surprisingly different from those of the $2p^5 3p$ g-values. Attempts to calculate the g-values from the parameters determined by Bartberger for the $2p^5 4p$ configuration lead to the same difficulty as experienced by Inglis and Ginsburg in the comparison between theory and experiment for the $2p^5 3p$ configuration, although the g-sums are very satisfactory. Practically all of the lines involving the $2p^5 3d$ and $2p^5 4d$ configurations show incipient Paschen-Back effect. The calculations for the study of these lines are very complicated but can be attacked by the methods of quantum mechanics. There is evidence for the appearance of forbidden transitions of the type $j = 2$ to $j = 0$ on several of the plates.

119. On the Measurement of Hyperfine Structure Separations. D. H. Tomboulian and R. F. Bacher, *Cornell University.*—In the determination of electric quadrupole moments from hyperfine structure data, it is very desirable to make accurate measurements of certain intervals. With a view to ascertain and possibly increase the precision of such measurements, an experimental study has been made using a Fabry-Pérot interferometer in conjunction with a Zeiss three prism spectrograph. With the three component line λ7852 $5s6p\ ^1P_1 \rightarrow 5s6s\ ^1S_0$ of In II as a test, spectrograms have been obtained with 3, 5, and 8 mm separators. The use of these different separators completely changes the grouping of the components. Measurements of 3 plates at 3 mm separation and 3 plates at 5 mm separation show for the larger interval a maximum deviation from the mean of 0.3×10^{-3} cm^{-1}; and for the smaller interval (which does not seem to be quite as favorable for accurate measurements) a maximum deviation of 0.6×10^{-3} cm^{-1}.

Saturday Morning at 9:30 o'clock

George Washington University

Corcoran Hall, Room 10

120. Diffuse Reflection of Neutrons from a Plane Surface. O. Halpern, R. Lueneburg and O. Clark, *New York University.*—The authors have solved rigorously the problem of multiple scattering of neutrons incident with an arbitrary velocity distribution upon the plane surface of an infinitely extended body which scatters the neutrons according to the following three assumptions: (1) The scattering is spherically symmetrical in the laboratory

frame of reference. (2) There exists a finite probability for capture. (3) The absolute value of the neutron velocity remains constant. These three assumptions are approximately verified in nature for nonhydrogenic bodies of not too small an atomic weight and all neutron velocities, and for hydrogenic bodies and slow neutrons. The problem is solved with the help of an exact integration of the modified Fokker integro-differential equation. The solution leads to explicit numerical expressions for the coefficient of reflection as function of the ratio of capture cross section to scattering cross section. Comparison with the experiments so far available leads to values for hydrogen which are 50 percent to 100 percent higher than those obtained by Fermi and collaborators. Work on other geometrical arrangements and generalizations as far as the scattering properties of the body are concerned is in progress.

121. Experimental Study of Neutron-Proton Interaction. CURTIS W. LAMPSON, *Princeton University;* DONALD W. MUELLER, *Cornell University;* AND HENRY A. BARTON, *American Institute of Physics.*—A neutron source was provided by bombarding a target of deuterium compound with a 1 mm diam. beam of deuterons. Neutrons passing into a photographic emulsion encounter protons which recoil and, on their passage through the emulsion, render developable the grains of silver bromide in their path. Microscopic examination of the developed plate reveals tracks containing as many as 45 grains and as great as 75μ in length. The length orientation and position with respect to neutron source of these tracks may be accurately measured. From these data the recoil angle of a track may be computed and thus a statistical distribution of the number of tracks with respect to recoil angle obtained. This distribution curve has a maximum between 20–30 degrees. If neutron-proton impacts could be regarded as occurring between elastic spheres the maximum should lie at 45 degrees. This discrepancy indicates the existence of comparatively long range forces between the neutron and proton. Assuming conservation of energy and momentum the energy of the impinging neutrons can be found and appear to form a fairly homogeneous group of 2.55 Mev.

122. Scattering of Neutrons of Homogeneous Energy by Protons. P. GERALD KRUGER, W. E. SHOUPP AND F. W. STALLMANN, *University of Illinois.*—An investigation of the angular scattering of neutrons, by protons, has been carried out. The neutrons were produced by bombarding D_2O ice with 1 Mev volt deuterons from a cyclotron. These neutrons have a homogeneous energy of 2.55 Mev.[1] The distance between the neutron source and the cloud chamber, in which the scattering was observed, was 52 cm. Two runs have been made. The first run was made with hydrogen gas in the chamber and 250 recoil proton tracks were measured. During the second run the chamber was filled with methane and 560 pictures were taken. In the latter run 3 to 10 recoil protons were observed per picture. At the time of writing only 250 tracks from the second run have been measured. The distribution from both runs is essentially the same and shows a peak at angle $\phi = 25°$ with respect to the forward direction. When these data are plotted on a curve whose ordinate is the percent scattered at angle ϕ per unit solid angle and whose abscissa is the scattering angle ϕ, the curve nearly coincides with that of Harkins *et al.*[2] and Kurie.[3] Since all these curves are quite similar the angular distribution of the scattered protons seems to be independent of the neutron energy.

[1] Bonner and Brubaker, Phys. Rev. **49**, 19 (1936).
[2] Harkins *et al.* Phys. Rev. **50**, 980 (1936).
[3] Kurie, Phys. Rev. **44**, 463 (1933).

123. Scattering of Neutrons Absorbed by Iodine. ALLAN C. G. MITCHELL AND R. N. VARNEY, *New York University, University Heights.*—A quantitative study of the scattering of neutrons absorbed by iodine (I group) was undertaken to see if there was any marked dependence of scattering cross section on neutron energy. The method used was that previously described.[1] Neutrons, slowed down by paraffin, were filtered through 0.218 g/cm^2 of Cd to absorb the thermal neutrons. CHI_3 deposited in a thin layer of paraffin served as a detector of I neutrons. Complete scattering curves were run for the elements Fe, Ni, Pb and Ag, and relative cross sections for scattering determined on the same basis as that previously used.[1] The results showed that, for the first three elements, there was no marked difference between the scattering cross section for I neutrons and that for the groups *A*, *B*, *C*, and *D*. The scattering curve for Ag was similar to that obtained using a silver detector and neutrons filtered through Cd; 2 cm of Ag scatters back 25 percent of the incident neutrons.

[1] A. C. G. Mitchell, E. J. Murphy and M. D. Whitaker, Phys. Rev. **50**, 133 (1936).

124. Neutron Absorption Limit in Cadmium. M. STANLEY LIVINGSTON AND J. G. HOFFMAN, *Cornell University.*—In order to find the high energy limit of neutrons absorbed in Cd the absorption of the transmitted neutrons in boron was measured. Neutrons from a Rn-Be source in a paraffin sphere (10.75 cm radius) were detected in a boron fluoride ionization chamber with a linear amplifier and counter. The chamber was shielded with 0.5 mm Cd and 0.5 g/cm^2 of B_4C except for an aperture facing the sphere. Boron absorption curves were taken with and without 0.5 mm Cd using B_4C and Pyrex glass, respectively, in front of the aperture. After applying a 10 percent obliquity correction (calculated) the slow neutron absorption coefficient is found to be 36 cm^2/g B, in agreement with Amaldi and Fermi. The Cd penetrating neutrons are inhomogeneous in energy and therefore are not absorbed exponentially but according to the law: $(1-e^{-x})/x$, where $x = K\delta$ and K is the absorption coefficient for neutrons just penetrating Cd. K is found to be 9.5 cm^2/g B. The number of counts produced by neutrons penetrating 0.5 mm Cd is 8.4 percent of the total; 5.7 percent are absorbable in thick boron. The remaining 2.7 percent are probably due to fast neutrons disintegrating B or F or stray neutrons entering the chamber through the shields.

125. Neutron Absorption Limit of Cadmium. J. G. HOFFMAN AND H. A. BETHE, *Cornell University.*—The ratio of the absorption coefficients of Cd penetrating and thermal neutrons is $9.5/36 = 0.264$ (see preceding abstract). There-

fore the absorption limit of Cd is $kT/.264^2=0.37$ volt. Thus Cd absorbs not only thermal neutrons but also neutrons of considerably higher energy. This result may be compared with that of the wheel experiment of Rasetti and others[1] which gives the dependence of the capture probability p on the energy at thermal energies $(d \log p/d \log E)_{kT} = 0.28$. Accepting the Breit-Wigner formula for the capture probability, $p \sim [(E-E_r)^2+\frac{1}{4}\Gamma^2]^{-1}$, the resonance energy E_r and the width of the resonance level Γ may be determined. The result is $E_r=0.16$ volt, $\Gamma=0.16$ volt which agrees with that obtained from the absorption of D neutrons in Cd[2]. The width is of the same order as for other neutron resonance levels. With these data, the cross section is almost independent of the energy from thermal energies up to about 0.2 volt. From the absolute cross section, the "neutron width" may be determined; it is about $\Gamma_n=1.7\times10^{-3}$ volt, i.e., about the same as for Rh, Ag, etc.

[1] Phys. Rev. **49**, 104 (1936).
[2] Amaldi and Fermi, Phys. Rev. **50**, 899 (1936).

126. Absorption of Resonance Neutrons. H. H. GOLDSMITH AND J. H. MANLEY, *Columbia University.*—For a substance in which a single resonance level is effective, the neutron absorption coefficient varies as v^{-5}, provided the neutron energy is much greater than both the resonance width and the resonance energy. This v^{-5} law affords a sensitive method for measuring neutron energies in a limited range; different energy regions may be explored by choosing appropriate absorbers. In previous work the absorption in Cd was measured in order to check the boron v^{-1} law in the neighborhood of 1 ev. The method has now been extended, using Hg absorption to study the same region, and using Ir absorption to investigate the region of the I, As and Br resonance levels. The relative positions of the Gd, Sm, Hg, and Cd levels have been determined by the boron method. The order of the average energies of these levels as indicated by these measurements is $E_{Hg}>E_{Cd}\sim E_{Sm}>E_{Gd}$. Experiments in which boron absorption was replaced by Ag absorption led to similar results. Absorption experiments in which a V detector was used without a Cd filter yielded cross sections which were approximately equal to the C neutron cross sections. Similar results with Dy detector show that these elements are essentially C neutron detectors.

127. Neutron Energy Levels. J. H. MANLEY, H. H. GOLDSMITH AND J. S. SCHWINGER, *Columbia University.*—Absorption measurements have been performed on Rh, In, and Ir with the same substance as both absorber and detector. The experimental absorption curves have been compared with theory, taking into account the angular distribution of the neutrons and the absorption in the detector of both neutrons and electrons. In the case of Rh (detector thick with respect to electronic absorption) the experimental curve may be fitted by assuming a single, narrow resonance level with a cross section at resonance of about 9000×10^{-24} cm^2. For thick detectors and large absorber thickness the calculated curve is independent of the angular distribution of the neutrons and is practically independent of the cross section at resonance, being essentially determined by the electronic absorption coefficient, μ_e. It may be shown that the transmission in this region is approximately $(\pi\mu_e x)^{-\frac{1}{2}}$ where x is the absorber thickness. For thin detectors, however, the corresponding expression is $(\pi\mu_{Res}x)^{-\frac{1}{2}}$ where μ_{Res} is the absorption coefficient for homogeneous neutrons with the resonance energy. The correlation of the experimental data on resonance widths, resonance energies, and resonance cross sections with the theory will be discussed.

128. Experiments on the Magnetic Moment of the Neutron. P. N. POWERS, H. CARROLL AND J. R. DUNNING, *Columbia University.*—The experiment described recently,[1] involving the transmission of neutrons through three iron plates magnetized to saturation and then demagnetized, has been repeated using neutrons which are emitted from an "howitzer" cooled to approximately the temperature of liquid air. The results of this experiment are shown in Table I.

TABLE I.

	Total No. Counts	No./Min.	Differences
Magnetized	70,578	157.66±.60	4.7±.8
Demagnetized	68,517	153.01±.58	87.2±.8
Background with Cd	10,972	65.8 ±.6	

These differences represent a 5.3 percent±1.0 percent increase in cold neutron transmission when the plates are magnetized to saturation as compared to a 3.6 percent ±0.6 percent increase for room temperature neutrons.[1]

Similar runs were made using only two of the plates. The results obtained indicate a 1.9 percent±0.7 percent effect for the room temperature neutrons and a 2.9 percent±0.7 percent effect for the cold neutrons. The increase is proportionately the same with two plates and with three plates, although with two plates the effects are so small that the increase is not significant.

In these experiments the "howitzer" was cooled by circulating liquid air through copper tubing embedded in the paraffin. The temperature of the paraffin averaged 105°K. Although it has not been ascertained that the neutrons have a Maxwellian distribution of velocities at this low temperature, these results are in qualitative agreement with theory.[2-4]

[1] Powers, Beyer and Dunning, Phys. Rev. **51**, 371 (1937).
[2] Bloch, Phys. Rev. **50**, 259 (1936).
[3] Hoffman, Livingston and Bethe, Phys. Rev. **51**, 214 (1937).
[4] Schwinger. (In Process of Publication.)

129. The Yield of Protons and Neutrons from the Deuteron-Deuteron Reaction. RUDOLF LADENBURG AND MORTON H. KANNER, *Princeton University.*—We have measured the yield of protons and neutrons by bombarding targets of heavy ice with deuterons between 100 and 200 kv. The arrangement was essentially the same as before used by Ladenburg-Roberts (Phys. Rev. **50**, 1190 (1936)). The cross section for scattering of the neutrons which has to be known for calculating the absolute yield of neutrons in our method, was determined for the homogeneous neutrons used. The result is that at 1μA and 100 kv the proton yield is 2.3×10^5 per second, taking into account the anisotropy of the yield; the neutron yield turned out to be 4, 5 times as large. When slowed down by paraffin, the neutrons were

equivalent to 43 mc, Ra mixed with fine Be powder, so that 1 mc produces 23,000 neutrons per second (Amaldi-Fermi find 27,000 per second per mc). The effective cross section for the yield is constant within 2 percent in the investigated energy range; its absolute value is 21×10^{-26} for the neutron yield, but is subject to some uncertainty on account of the reduction of the results to a pure deuteron target.

130. Disintegration of the Deuteron under Fast Alpha-Particle Bombardment. H. L. SCHULTZ, *Yale University.*—Several attempts to observe the disintegration of the deuteron under bombardment by alpha-particles according to:

$$_1H^2+{}_2He^4\rightarrow{}_1H^1+{}_0N^1+{}_2He^4$$

have been made. Rutherford and Kempton using Po alpha-particles found no detectable yield of neutrons, and subsequent experiments of Dunning with RaC′ particles indicated a very small effect if any. In either case, however, the method of detection applied to fast neutrons only; moreover, in the latter case any slight yield might be explained by the photo-disintegration of the deuteron. In view of the theoretical importance of this reaction, it was thought desirable to extend the above measurements to higher energies (ThC′ particles) using a more sensitive neutron detecting arrangement, especially for lower energies. Accordingly, with a neutron detector consisting of a BF_3 filled ionization chamber surrounded by paraffin and connected to a linear amplifier, a large number of counts were taken alternately with the source exposed to 1.2 cm air equivalent of D_2 gas and with the source covered by a thin Cu plate. The data obtained in this manner indicate a small yield. Comparison with the yield from N^{14} under identical conditions gives a cross section roughly in agreement with theoretical estimates of Massey and Mohr. Preliminary experiments with RaC′ sources give no indication of a yield.

SATURDAY AFTERNOON AT 2:00 O'CLOCK

George Washington University

Corcoran Hall, Room 10

131. The Beta-Ray Spectrum of Radium E. J. S. O'CONOR, S.J.,* *Massachusetts Institute of Technology.*—The distribution in energy of electrons from radium E was examined by means of a magnetic spectrometer using Geiger-Müller coincidence counters. Special precaution in the form of a baffle system was employed to reduce scattering effects. The radioactive material was examined under different conditions of source strength, mounting material and aperture of defining slits with a view to determining the effect of these variables on the experimental distribution curve. It is concluded that the position of the high energy *experimental* end point depends on the source strength used as well as the width of the defining slits. Below a definite source strength and with narrow defining slits the results from radium E mounted on nickel and on platinum were self-consistent. Using data from these latter distribution curves an analysis was made to test the validity of the Fermi and the Konopinski-Uhlenbeck theories of beta disintegration after the manner introduced by Kurie, Richardson and Paxton. It was found that the linear relation, used as a criterion, did not exist for the Fermi function but appeared in the "K-U" plot within the limits of error set by statistical fluctuations and finite slit widths. From extrapolation of the "K-U" plot the high energy end point was found to be 1.25 Mev±0.03 Mev.

* Now at Woodstock College, Woodstock, Maryland.

132. Shape of the Beta-Ray Distribution Curve of Radium E at High Energies. LAWRENCE M. LANGER AND MARTIN D. WHITAKER, *New York University, University Heights.*—The beta-ray spectrum of radium E was measured by means of a magnetic spectrometer and coincident counters. Because of the strong source available, and the low background of the detecting mechanism, it was possible to obtain significant data much closer to the end-point than has been done heretofore. The distribution was found to end, without a tail, at $H\rho=5330$ oersted-cm, or 1.17×10^6 electron volts. The Fermi and K-U plots of the experimental data do not give straight lines as predicted by the theory. Extrapolation of the straight part of the K-U plot gives an end-point 17 percent higher than that observed.

133. The Calculation of Phase Shifts in Scattering Problems. E. L. HILL, *University of Minnesota.*—The calculation of elastic scattering problems in quantum mechanics is reducible to that of finding the asymptotic forms of the solutions of a family of equations of the type

$$g_L''+\gamma_L g_L=0, \quad L=0, 1, 2, \cdots,$$
$$\gamma_L(x,\epsilon)=\epsilon+\varphi_L(x)+\frac{B_L(x)}{x}-\frac{L(L+1)}{x^2},$$

where $B_L(x)$ and $\varphi_L(x)$ are finite at $x=0$. This equation is transformed as follows:

$$\gamma\gtrless0, \quad g=a(x)\sin\sigma(x); \quad g'=\gamma^{\frac{1}{4}}a(x)\cos\sigma(x);$$
$$\sigma'=\gamma^{\frac{1}{2}}+\tfrac{1}{4}(\ln\gamma)'\sin2\sigma; \quad (\ln a)'=-\tfrac{1}{4}(\ln\gamma)'(1+\cos2\sigma);$$
$$\gamma\lessgtr0, \quad g=(\chi_1+\chi_2); \quad g'=-(-\gamma)^{\frac{1}{2}}(\chi_1-\chi_2);$$
$$\chi_1'=-(-\gamma)^{\frac{1}{2}}\chi_1-\tfrac{1}{4}[\ln(-\gamma)]'(\chi_1-\chi_2);$$
$$\chi_2'=-(-\gamma)^{\frac{1}{2}}\chi_2+\tfrac{1}{4}[\ln(-\gamma)]'(\chi_1-\chi_2).$$

These transformations are regular except at $x=0$ and at points for which $\gamma=0$, but investigation shows that $\sigma(x)$ and $\chi=\chi_1/\chi_2$ do nothing peculiar there, even though $a(x)$ does. For the study of the asymptotic form of g, the function $\sigma(x)$ is important because its equation can be integrated (numerically) without evaluating $a(x)$, and the

phase shifts computed directly. If $\gamma<0$ for $x<x_1$ and $x>x_2$, and $\gamma>0$ for $x_1<x<x_2$, a discussion shows that an approximate "quantum condition" for a proper function with n nodes in (x_1, x_2) is

$$\sigma(x_2)-\sigma(x_1)=(n+\tfrac{1}{2})\pi+\pi.$$

When γ'/γ is small compared to $\gamma^{\frac{1}{2}}$ the standard approximate form $\sigma(x)=\sigma(x_0)+\int_{x_0}^{x}\gamma^{\frac{1}{2}}dx$ can be used. Boundary conditions are as follows (continuous spectrum):

$$L=0, \quad \sigma_0(0)=0,$$
$$L>0, \quad \chi_L(0)=\{[L(L+1)]^{\frac{1}{2}}-(L+1)\}/\{[L(L+1)]^{\frac{1}{2}}+L(L+1)\},$$
$$\chi_L\to-1 \quad \text{as} \quad x\to x_1-0,$$
$$\sigma_L\to 0 \quad \text{as} \quad x\to x_1+0.$$

134. The Scattering of Protons by Protons. L. R. HAFSTAD, N. P. HEYDENBURG AND M. A. TUVE, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—Observations on the scattering of protons by protons have been extended to the energy-region below 600 kv by using a Geiger point-counter to detect the scattered and recoil protons. The angular variation of these protons was investigated at the fixed voltages, 200, 300, and 400 kv. The data definitely indicate a large decrease in the ratio of the observed scattering to Mott's theoretical scattering at 45° in the region of 300 to 400 kv, as would be expected on the basis of the attractive forces demonstrated by our measurements a year ago. The absolute values of the scattering are not yet satisfactorily quantitative due to the presence of residual counts probably caused by ultraviolet light.

135. The Multiple Scattering and Stopping of Electrons. MORRIS E. ROSE,* *Cornell University.*—The scattering and stopping of electrons in a thick foil have been investigated; the foil is considered thick enough so that it is necessary to treat multiple scattering. Because at high energies (above 1 Mev in Al) the stopping predominates and at lower energies the scattering is more important, it is permissible to treat each effect separately in the two energy regions. The angular distribution and "Umwegfactor" of electrons of any primary energy transmitted by a foil have been found. At low energies the scattering may be treated as a diffusion process with energy dependent diffusion coefficient. Taking into account both stopping and scattering a formula has been derived for the transmitted intensity of an initially homogeneous beam. This formula is easily generalized to arbitrary energy distribution and thus absorption curves can be found for the electrons (positrons) from artificial radioactivity or for the secondaries generated by γ-rays. For measurements of γ-ray energy it is important to have the relation between the half-value thickness, $d_{\frac{1}{2}}$, and γ-ray energy.[1] This has been obtained for Al. The results show that the assumption of linearity[1] is unsatisfactory. The computed $d_{\frac{1}{2}}$ in Al for the ThC″ (2.62 Mev) γ-ray is 0.27 g/cm² in exact agreement with the measured value of Fleischmann.

* This work was supported by a grant-in-aid from the Penrose Fund of the American Philosophical Society.

[1] F. Rasetti, Zeits. f. Physik **97**, 74 (1935); R. Fleischmann, Zeits. f. Physik **103**, 113 (1936).

136. Small Angle Scattering of Fast Electrons. J. B. H. KUPER, *Princeton University.*—A large sized electron scattering apparatus with an electrostatic energy analyzer has been used to study the elastic scattering of electrons with energies between 50 and 90 kilovolts in argon, neon, helium and hydrogen. The construction of the apparatus permits measurements in the range of angles from 0° to about 6°, but in the lighter gases it was impossible to carry the measurements beyond 3°, owing to a background current (presumably electrons multiply scattered from the walls). In order to secure sufficient intensity gas pressures of the order of 5×10^{-2} mm Hg (with differential pumping maintaining a pressure roughly 1000 times lower in the analyzer) and bombarding currents of about 3 microamperes were used. The work is being extended by a study of the inelastic scattering which necessitates the use of a counter in place of the Western Electric electrometer tube used for elastic scattering. The experimental curves seem to be in good agreement with the quantum mechanical predictions based on Born's approximation and the Hartree fields.

137. Electron Scattering and the Action of a Collector Electrode in an Electron Swarm. ERNEST G. LINDER, *RCA Manufacturing Co. Inc., Camden, N. J.*—It is shown that in cases where electrons execute cyclic orbits such that they return periodically to the neighborhood of the cathode, as in magnetrons and positive grid tubes, considerable electron scattering may occur. Due to this a fraction of the orbital velocity is converted to random velocity, and electrons, on the average, are therefore unable to return to the cathode surface, or to the surface of any collector at the same potential. If the scattering is such as to lead to a Maxwellian distribution, a virtual cathode forms about the real cathode or collector, its temperature being given by $\bar{V}e=(3/2)kT$, where $\bar{V}e$ is the part of the orbital energy converted to random energy. The potential difference between the real cathode, or collector, and the virtual cathode is also $\bar{V}$. For a collector not at zero potential the potential difference is $V_g-\bar{V}$. The Langmuir-H. M. Mott-Smith expression for current to an internal collector with a retarding field is applicable, and yields

$$I_g=\frac{(1-f)r_0 I_c}{r_1+r_2}\exp\frac{e(V_g-\bar{V})}{k(T+T_0)},$$

where I_g is the collector current, f the electron reflection coefficient, r_0 the collector radius, r_1 and r_2 the virtual cathode radii about the cathode and collector, respectively, I_c the circulating current, and T_0 the filament temperature. Experimental data are in agreement with this expression.

138. The Compton Effect with Gamma-Rays. ROBERT S. SHANKLAND, *Case School of Applied Science.*—The studies using Geiger-Müller counters[1] of directional and coincidence effects in the Compton scattering of the gamma-rays from RaC have been continued. The scatterer used is an aluminum foil of thickness 0.00165 cm. Two complete series of observations have been made. In one series the electron counter was placed in the azimuth $+\theta$ demanded by the photon theory where 195 discharges

were recorded coincident with those in the gamma-ray counter set in the azimuth ϕ. A comparison experiment showed that 94 of these coincidences were probably due to chance. In the second series of observations the electron counter was set in the azimuth $-\theta$, symmetrical with respect to the first position, but on the opposite side of the incident beam of radiation. In this position 141 coincidences were observed of which 105 were probably due to chance. Thus the ratio of the number of true coincidences to the total number observed is 0.52 in the predicted position of the electron counter, and 0.26 in the other position. The observation of true coincidences in the $-\theta$ position of the electron counter is due to the deflection which the recoil electrons may suffer in leaving the foil. This experiment checks the predictions of the theory in two respects. First, it shows a time-coincidence between the scattering of the gamma-ray and the appearance of the recoil electron. Second, the results are consistent with the angular relationship predicted by the Compton theory. The results may be interpreted as confirming this relationship to within $\pm 21°$.

[1] R. S. Shankland, Phys. Rev. **49**, 8–13 (1936); **50**, 571 (1936).

139. A Stable Source of Focused Ions. LLOYD P. SMITH AND GEORGE W. SCOTT, JR., *Cornell University.*—A considerable modification of the ion source already described (L. P. Smith and H. A. Carlock, Phys. Rev. **49**, 646 (1936)) has been made so as to produce a focused beam of positive ions when a gas is bombarded by a focused beam of electrons. Gas is admitted to a cylindrical chamber where the pressure is somewhat higher than in the remainder of the system. Electrons are produced by a cylindrical nickel cathode which is oxide coated on the interior and indirectly heated by a suitable tungsten heating coil. When proper potentials are applied to the ionization chamber and the cathode, which is placed close to the former and coaxial with it, the combination acts as a convergent electrostatic lens which focuses the electrons at the interior of the chamber. This, together with a somewhat larger cylinder located at the opposite end of the cathode and coaxial with it, served to focus the positive ions since such a lens system possesses focal properties which is independent of e/m. The ion current, as measured by a Faraday cylinder which was shielded and biased to remove all unfocused ions and possible secondary electrons from the measuring electrode, was found to be very steady when hydrogen was used, the pressure of which was about 2×10^{-4} mm Hg in the main part of the system.

140. Drift of Ions and Electrons under the Action of Concentration Gradient, Electric and Magnetic Fields. LEWI TONKS, *Research Laboratory, General Electric Company.*—The Boltzmann equation must be satisfied by any mobility equations when the drift velocities are put equal to zero, irrespective of the presence of a magnetic field. As a consequence, concentration gradient and field strength components must always appear in the combination $(neX/kT-\partial n/\partial x)$ which, set equal to zero, is a form of the Boltzmann equation. Neither Townsend's original equations[1] nor Huxley's later attempt at refinement[2] conforms to this requirement. Satisfactory equations from this point of view are: $nu/K_H=(neX/kT-\partial n/\partial x)+\omega\tau(neY/kT-\partial n/\partial y)$ and $nv/K_H=(neY/kT-\partial n/\partial y)-\omega\tau(neX/kT-\partial n/\partial x)$ where the magnetic field H is parallel to z, u and v are the drift components, $\omega=eH/mc$, τ is the mean free time of an ion, and $K_H=(1+\omega^2\tau^2)^{-1}K$ is the magnetic diffusion coefficient, K being the nonmagnetic one. A deducible conclusion which is important for high current arcs is that in the direction of drift, the motion is the same as that arising from the electric field and concentration gradient components in that direction alone in the absence of all other components and of the magnetic field itself.

[1] Proc. Roy. Soc. **86**, 571 (1912).
[2] Phil. Mag. **23**, 210 (1937).

141. Coefficient of Combination between Small Ions and Large Ions. G. R. WAIT, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—The value of the coefficient of combination between small ions (mobility about 1.5 cm/sec./volt/cm) and the large ions (mobility about 5×10^{-4} cm/sec./volt/cm) has been determined from data simultaneously obtained on small ion and large ion concentrations in the atmosphere and on the rate of small ion formation. The average value found for the coefficient was about 9.0×10^{-6} with a considerable range in the values, the largest being more than two times the smallest. The combination coefficient was found to vary with temperature and absolute humidity of the air, the correlation with both being between $+0.5$ and $+0.7$. One interpretation of the results is that the combination coefficient varies because the size of the particle of which the large ion is composed varies with the absolute humidity. Evidence substantiating this interpretation is presented.

142. Convection Currents in Mercury Arcs. CARL KENTY, *General Electric Vapor Lamp Company.*—Convection currents in high intensity lamps (2.9 amp. arcs in 33 mm tubes in Hg vapor at 1 atmosphere) are studied by observing under a red glass the motions of incandescent particles of MgO. In the arc stream the smaller particles vaporize and enough light is produced for their motions to be photographed on a moving film (red filter). In the vertical position a strong upward current exists in the core and a much slower current of cold gas downward near the walls. On half wave operation a dark space of 2 cm develops at the bottom during the 0.01 sec. zero current period. This gives an upward core speed of 200 cm per sec. on the view that rising hot gas is being replaced by cold gas from below. Viscosity calculations following Elenbaas using his temperature distribution (5400°K at axis for this case) give a speed of around 90 cm per sec. Horizontal operation requires a magnetic field to keep the arc from bowing up. Force measured: 1.8 dynes per cm. Force roughly calculated using Archimedes principle and Elenbaas' temperature (density) distribution: 1.3 dynes per cm. Magnetic reaction forces the gas rapidly downward through the core, particles show.

Saturday Afternoon at 2:00 o'clock

George Washington University

Corcoran Hall, Room 29

143. The Frequencies and Nodal Lines on Circular Metallic Plates.* R. C. Colwell, A. W. Friend and H. C. Hardy.—The mathematical solution for circular plates was developed by Kirchhoff in 1850. His equation takes the form $J_n(kr)+\lambda J_n(ikr)=0$. When the plate is clamped at the center two more terms appear in the solution and the equation is $\alpha J_n(kr)+\beta G_n(kr)+\gamma I_n(kr)+\delta K_n(kr)=0$ (Southwell). It is possible to test these equations by means of an oscillating valve working into a magnetostrictive oscillator. Experiment shows that there is complete agreement between theory and experiment in so far as the nodal lines are concerned provided they are circles or diameters or combinations of these. The frequencies are in agreement for low values but above 5000 r.p.s. the necessary approximations in the theory cause a considerable error in the calculated frequencies.

* To be read by title.

144. Electrophoresis and Electroosmosis of Drugs Through the Skin.* Harold A. Abramson, *Medical Service of Dr. George Baehr, The Mount Sinai Hospital, New York City.*—It has been customary to apply the classical equations for ion and water transport across the human skin when considering the conditions favorable to electroosmosis of certain chemical substances, especially drugs. These classical equations for ion transport probably never apply across the skin but only to the movement of ions up to the skin. In the pores of the skin itself, a new set of conditions exist which may lead to the complete reversal of the effect anticipated from the classical equations. The classical equations may not be valid because of correction terms which include (1) decreases (increases) in the transfer number of effective ions in the pores of the skin; (2) the addition of an electroosmotic term; (3) reversal of the sign of the electrokinetic potential of the skin; (4) surface conductance in the pores of the skin. Application of these principles has as yet been only qualitative for a system so complicated as the human skin. They have, however, been made successfully with low current densities to the anesthetization of the skin with procaine as a preparatory measure for intradermal skin tests in hay-fever and allied conditions. These principles are also of service in elucidating the mechanisms of the electrical transfer of histamine through the skin irrespective of the charge of histamine ion.

* To be read by title.

145. A Physical Analysis of the Dead Beat Mechanism of the Auditory Ossicles. Otto Stuhlman, Jr., *University of North Carolina.*—Bekesy (Akust. Zeits. **1**, 13 (1936)) shows by optical means the dead beat character of the plucked vibrations of the tympani and malleus. How does the ossicle chain transmit this motion to the stapes? A 24X scale model of the ossicles was constructed, with accurate scale reproductions of the articulating surfaces. Model mounted on horizontal turntable. Malleus, anterior process down on axis. Incus short crus up 80 degrees with axis of rotation. Lever arms 5–4–3. Rotation of malleus produced displacements of lenticular process of incus, measured with a 1/100 mm displacement gauge. One degree rotation of malleus produced via the articulation a superior, inferior, anterior and posterior displacement of 0.33, 0.75, 0.42 and 0.61 mm. Resultant motion makes 57 degree angle with axis of long crus. Helmholz' "Sperrzahne" here viewed as corrugations with no real locking properties. Force per degree displacement of malleus about 10 percent greater inward than outward, due to slope of corrugations. Stapes, possesses a Gothic superior arch and a parabolic inferior arch, bent 23 degrees downward. Gothic arch tension, parabolic arch compression. Thrust of incus up, articulation on inferior side of head. If motion of malleus is in, incus moves in, up and forward (anterior). If out, incus moves out, down and back (posterior). Resulting stapes motion, superior-anterior margin in, inferior-posterior margin out. First motion checked by stapedius tensor, second by tensor tympani making both in and outward motions of tympani dead beat.

146. The Time Lag in Gas-Filled Photoelectric Cells. A. M. Skellett, *Bell Telephone Laboratories, Inc.*—The origin of the time lag in gas-filled photoelectric cells has never been satisfactorily explained. Measurements were made of the time lag in such a cell having a small anode concentric with a spherical cathode, using variable light and constant potential. The light intensity was varied in accordance with the expression $A+B\sin\omega t$ and the alternating component of the output current of the cell was measured at frequencies of illumination varying from 60 to 20,000 c.p.s. The resulting response *vs.* frequency characteristic exhibited maxima and minima, a maximum falling at twice the frequency of the first minimum. This indicates a time lag in the output current equal to half the period of the light variation at the first minimum. The value thus determined is in excellent agreement with the value calculated from the positive ion mobility on the basis that the lag is due simply to the transit time of these ions. In other designs of cells the effect is obscured by secondary emission at the cathode though the mechanism which causes the lag is undoubtedly the same.

147. A Continuously Sensitive Cloud Chamber. Alexander Langsdorf, Jr., *Massachusetts Institute of Technology.*—The thermally activated diffusion cloud chamber previously described[1] has been further developed. As before, a vapor is diffused vertically downward through a permanent gas from the heated top to the refrigerated bottom of a chamber, where it condenses. In an inter-

mediate region supersaturation is sufficient to show tracks caused by ionizing particles. With proper regulation, the present chamber should show tracks in a volume about four inches deep and thirty inches in diameter. The chamber is built to allow operation with a partial vacuum; an air-lock arrangement permits introduction of radioactive samples during operation. A general rain of spontaneously formed droplets[1, 2] probably cannot be eliminated, but by careful regulation of all variable quantities it should be maintained at a low enough density to permit photography of the ion tracks. In addition to uses in nuclear and cosmic-ray research, this cloud chamber offers several possibilities in the study of the physical phenomena attending supersaturation and condensation.[3]

[1] A. Langsdorf, Jr., Phys. Rev. **49**, 422 (1936).
[2] R. E. Vollrath, Rev. Sci. Inst. **7**, 408 (1936).
[3] L. Farkas, Zeits. f. physik. Chemie **125A**, 236 (1927); M. Volmer and H. Flood, Zeits. f. physik. Chemie **170A**, 273, 286 (1934).

148. Grain Spacing of Alpha-Ray, Proton and Deuteron Tracks in a Photographic Emulsion. T. R. WILKINS AND H. J. ST. HELENS, *University of Rochester.*—The difference in the average separation of the grains in a photographic emulsion traversed by alpha-rays, protons and deuterons promises to provide an extremely valuable tool in nuclear research. The special Ilford R2 emulsion made for us has been exposed to ThC′ alpha-rays and to protons and deuterons from cyclotrons. An extended sensitometric study has indicated 3 min. development in D11 at the usual temperature (62°F). The tracks were viewed under a magnification of 900 (4 mm 45X objective and 20X hyperplane eyepiece) and dark field illumination. The average separation for all three types of particles increases with the length of the track. Graphs showing the scatter and the average grain spacing will be presented. The average grain separations for the last five grains of the tracks for this batch of the R2 emulsion were alpha 1.63μ deuterons 1.89μ protons 2.7μ. The technique has already been used by us in the study of cosmic-ray tracks.* Some further examples of its application to cosmic-ray proton group disintegrations obtained in plates exposed on Mt. Evans, Colorado, will be shown.

* National Geographic Society, Stratosphere Series No. 2.

149. Vacuum Tube Circuits for Scaling Down Counting Rates. E. C. STEVENSON AND I. A. GETTING, *Harvard University.*—The introduction of some regularity resulting from scaling down of randomly distributed pulses increases the efficiency of relatively slow mechanical counters by a ratio greater than to be expected from the scaling factor alone. The ultimate efficiency that can be reached is fixed by the resolving power of the scaling down circuit. If vacuum tubes are used instead of thyratrons, as in the Wynn-Williams scale of two, shorter resolving time as well as greater stability and durability is realized. Two very efficient circuits, operating at a great economy of plate power, have been devised and tested. The first circuit employs two tubes or one duplex tube in each halving section with a rectifying amplifier between each section. Its resolving time, found experimentally, is 1/2000 second. The second circuit employs four tubes or two duplex tubes in each halving section and an amplifier between each section. Its resolving time, found experimentally, is at least 1/20,000 second. At speeds greater than 1000 pulses per second, the circuit has successfully halved the input frequency of both sine waves as well as sharp pulses. These circuits should find application in recording rapid Geiger-Müller counter pulses and as adjuncts to frequency meters of limited range.

150. Discharge Mechanism and Characteristics of Geiger-Müller Counter Tubes. O. S. DUFFENDACK, M. M. SLAWSKY AND HAROLD LIFSCHUTZ, *University of Michigan.*—Experiments were made on counter tubes with 3 mil tungsten wire anodes and cathodes, 1 cm in diameter, of Al, Cu, Ni, and W. A, air, O_2, and H_2 at various pressures were used. The volt ampere characteristic curves were correlated with the voltage count characteristics using a Neher-Harper coupling circuit and a single thyratron operating a high impedance Cenco counter. Reliable counting characteristics and long plateaus were obtainable only with counters whose cathode surfaces were completely cleaned by a glow discharge in H_2 previous to filling. Al cathodes gave no plateaus in any gas. H_2 gave the longest plateaus, A the shortest. The results are in general accord with the conclusions of Werner and indicate that the operation of the tubes involves the initiation of a corona discharge in which the amplification depends upon both the ionization of the gas by electron collisions and the extraction of electrons from the cathode surfaces. All counters were observed to increase in photoelectric sensitivity with increasing applied voltage. Metastable atoms and the work function of the cathodes seem to play important roles in limiting the range of the plateau.

151. Determination of the Counting Losses in Thyratron Recording Circuits. HAROLD LIFSCHUTZ, O. S. DUFFENDACK AND M. M. SLAWSKY, *University of Michigan.*—To determine the counting losses in single and scale of eight thyratron recording circuits operating a Cenco counter, a known source of random pulses was obtained by two methods. The first consisted in recording the pulses from a Geiger-Müller tube counter on the sound track of a movie film. The recording apparatus had a resolving power of 1/10,000 sec. Playing the film back at various speeds gave a known and variable source of random pulses. The second method involved the successive addition of a number of weak radioactive sources in an apparatus designed to insure the same scattering from each source whether used alone or with others operating a G-M tube counter. The single thyratron circuit was found to lose 1 percent of the counts at an input rate of only 50 per minute, the losses increasing linearly with the input rate. This introduces a large error in much early work done with single thyratron circuits. The losses depend on the width and the amplitude of the pulses, being least for narrow pulses and minimum amplitude. This dependence prevents application of a purely statistical theory to calculate the losses. Similarly, the recording losses are less with the Neher-Harper circuit than with conventional coupling.

152. An Improved Electrical Telegauge. WAYNE C. HALL AND ROSS GUNN, *U. S. Naval Research Laboratory, Washington, D. C.*—A useful remote reading device to measure displacements of the order of 10 wave-lengths of red light and greater has been developed. A carefully designed vacuum tube with element spacing capable of variation and controlled by an externally applied displacement, is incorporated in balanced electrical circuits in such a way that first order variations of emission, or filament and plate potential, are not indicated. A portable direct current meter indicates deflections which are accurately proportional to the imposed displacement. Stable displacement amplifications of 5000 are readily obtained in a single tube used with portable equipment. The device has a high natural period and follows cyclical or impulsive displacements quite accurately if the period of the applied displacement is greater than 1/10th second. At 17 cycles per second extraneous harmonics of 4 percent are found but these may be readily reduced by proper damping. Hysteresis and aging effects are small with proper design. The investigation is continuing.

153. A Quantitative Study of Mountain Building on an Unsymmetrical Earth. ROSS GUNN, *U. S. Naval Research Laboratory, Washington, D. C.*—The principle of isostatic equilibrium is discussed and restated in a useful form which takes account of superposed vertical stresses in the crust. A quantitative study of the deformations produced in the earth's elastic crust by tangential compressional forces is made. The calculated physical properties of a suboceanic compressional downfold agree well with those observed in certain long and narrow ocean deeps. The properties of a downfault in continental regions are similarly deduced and it is shown that such a deformation evolves ultimately into a great sedimentary prism or geosyncline. The processes which fold and ultimately uplift the prism to form a mountain chain are quantitatively considered. A quantitative theory of mountain building leads to a law of mountain heights in good agreement with observation. The considered mechanisms are consistent with the principle of isostasy and with the author's earlier estimates concerning the concentration of stresses at the boundaries of the great continents. It is concluded that the circum-Pacific mountain chains could only have been generated on an unsymmetrical earth resulting probably from a fission process much like that suggested in the author's binary star theory of the origin of the solar system. (Phys. Rev. **39**, 130, 311 (1932).)

154. A Combined Still and Diffusion Pump. WHEELER P. DAVEY AND R. J. PFISTER, *The Pennsylvania State College.*—K. C. D. Hickman[1] has traced the loss in efficacy of oil diffusion pumps to an accumulation of volatile matter which diffuses back past the jet. He proposes a combination still and pump "simple to construct, surprisingly difficult to render vacuum-tight." By using a nest of vertical concentric boilers we have overcome the difficulty. If the space between the top of the boiling oil and the condensate collector ring is filled with an appropriate still-packing, we have, in addition to the effect of the multiple boiler, the added advantage of the "packed column" type of still. A two-jet water-cooled jet still of the above design was built with glass exterior, brass jets, and brass inner boiler, using cotton string to fill the space between the glass and the brass. This was connected to a large McLeod gauge by means of a large rubber stopper made substantially vacuum tight by means of yellow vaseline. When charged with a mixture of water and *n*-butyl phthalate it rejected the water and within an hour gave an apparent vacuum, as measured on the McLeod gauge, of 2×10^{-6} cm Hg. This was in spite of evident charring of the cotton string. When charged with two volumes of *n*-butyl phthalate, one volume of acetone, and one volume of cyclohexane, it rejected the acetone and cyclohexane and in an hour gave again a measured pressure of 2×10^{-6} cm Hg. This is considered to be the vapor pressure of *n*-butyl phthalate at the temperature of our condenser.[1]

[1] K. C. D. Hickman, Jr. Frank. Inst. **221**, 215 (1936).

155. Production of Liquid Hydrogen Without the Use of a Compressor. J. E. AHLBERG AND W. O. LUNDBERG, *Johns Hopkins University* AND I. ESTERMANN, *Carnegie Institute of Technology.*—By using a "twisted tube" heat interchanger instead of the Linde or Hampson type interchanger, and by other simplifications in construction, it has been possible to build a hydrogen liquefier of great efficiency and small size. The heat capacity of the unit is low enough to make it possible to operate the liquefier from ordinary hydrogen cylinders without the use of a compressor. Using liquid nitrogen at a pressure of about 20 cm of Hg for precooling, about 16 percent of the hydrogen was liquefied at a flow of 1.6 cu. ft. per minute producing about 0.9 liter of liquid hydrogen per hour. It is possible to watch the progress of the liquefaction through an unsilvered strip in the Dewar vessel containing the heat interchanger and the expansion valve. The liquid nitrogen consumption amounts to about 7 liters per liter of liquid hydrogen.

156. A Type of High Potential Battery Which Combines Extreme Lightness with Long Shelf Life. WILLIS E. RAMSEY, *Bartol Research Foundation of The Franklin Institute. (Introduced by W. F. G. Swann.)*—In the conventional type of dry cell we may substitute for the usual zinc jacket a single turn of zinc wire, and allow the blotting paper which carries the electrolyte to provide a wall for the cell. Pencil graphite makes a very good substitute for the usual carbon rod. Cell units of this type may weigh as little as 0.60 gram per volt and be very satisfactory. A sheet of cardboard covered with a thin layer of Superla wax provides an excellent mounting for the units. A light but tight cardboard box will prevent evaporation. These cells are mounted dry and allowed to remain so until needed. Rejuvenation may be obtained by adding a drop or two of ammonium chloride to each unit with a medicine dropper. Repeated dehydration and rejuvenation fails to disturb the constancy of the potential (0.1 percent per week) and such a battery is activated only during periods of time when it is being used. Cell units have an internal resistance varying from 5 to 1000 ohms depending on moisture-temperature coefficient 0.04 percent per degree centigrade.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member one only of these will be assigned a place on the regular program while the others will be placed in a supplementary program to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for only at the session indicated.

157. A Molecular Ray Method for the Separation of Isotopes.* O. STERN, *Carnegie Institute of Technology.*—The method of balancing the force of gravity by a magnetic field should allow effective separation of isotopes, because the compensating inhomogeneity $dH/dr = Mg/M$ depends on M. With Li, for example, choosing dH/dr between the limits $6g/M$ and $7g/M$, only the isotope 6 is deflected upwards and by collecting the Li above the straight beam we get pure Li_6. The intensity, however, would be very poor because, for practical reasons, the beam would have to be several meters long. But we can make the beam much shorter, replacing gravity by centrifugal force. Then it is easy to make the acceleration at least 10^4 times larger than g. For this case the beam needs to be only a few centimeters long giving a much larger intensity. Of course dH/dr has to be correspondingly larger, about 10^4 gauss/cm for Li_6 and a centrifugal acceleration of 10^4 g. Since the needed accuracy is small and the field has to be rotated, it would be convenient to use a permanent magnet. This method will give a pure isotope like the mass-spectrograph.

* To be called for after paper No. 35.

158. Quantitative Spectrographic Analysis of Biological Material. II.* J. S. FOSTER AND C. A. HORTON, *McGill University. (Introduced by Professor G. B. Pegram.)*—An internal standard method of general applicability has been developed for quantitative spectrographic analysis of fresh plant tissue without ashing or chemical treatment. The results obtained for boron, using 200 mg of fresh material, are reproducible with variations rarely in excess of ten percent. A photometer for wedge spectrograms is described. It is designed to avoid the problem of finding the ends of the spectral lines and to give directly the relative intensities.

* To be called for after paper No. 50.

159. The Stark Effect in Iron, and the Contrast with the Pole Effect.* F. PANTER AND J. S. FOSTER, *McGill University. (Introduced by Professor G. B. Pegram.)*—Through the use of a quartz tube which operates on very small current the Stark effects for a few hundred iron lines have been examined in fields from 100 to 200 kv/cm. The results lend no support to the view commonly expressed that the pole effect is a pure Stark effect. The Stark displacement of a few lines is opposite to the pole shift, and generally speaking there is no quantitative correlation between the two effects. Since all iron terms known to be displaced by the electric fields are even, it is suggested that odd terms may yet be found with values which are rather well defined by the observed perturbations.

* To be called for after paper No. 158.

160. Effect of Crossed Electric and Magnetic Fields on the Helium Spectrum.* J. S. FOSTER AND E. R. POUNDER, *McGill University. (Introduced by Professor G. B. Pegram.)*—The visible spectrum of helium has been examined from a source in which the constant electric field (values range from 10,000 to 120,000 v/cm) is at right angles to the magnetic field of 26,000 gauss, and the direction of observation is perpendicular to each. The tips of the hollow poles of the magnet are the cathodes of a double canal-ray tube which sends beams in both directions along the lines of magnetic force. Light intensity is good, and the quality of the analysis is equal to the best secured in pure Stark effect. In accord with theory, the usual selection rule for Δm does not apply, and the magnetic splitting of Stark components shows marked asymmetry in the intensities.

* To be called for after paper No. 159.

161. Stark Effect in the HD and D_2 Spectra.* J. S. FOSTER, D. C. JONES, S. M. NEAMTAN, *McGill University. (Introduced by Professor G. B. Pegram.)*—The Stark effect in HD and D_2 has been investigated in the region from $H\beta$ to $H\alpha$. Light from a Lo Surdo source was analyzed by a stigmatic concave grating spectrograph having a dispersion of 3.8A/mm. Plates have been obtained with electric fields from 80 to 100 kv/cm and with deuterium concentrations from 50 percent to 95 percent. Practically all the lines classified by Dieke[1] in this region of intensity over 1 have been photographed. Many unclassified lines have been observed and their behavior in an electric field noted as of possible assistance in the further analysis of the normal spectra. In addition to extending the range of the work of Hasunuma,[2] the use of greater dispersion and of plates with a practically pure deuterium spectrum has made possible the clarifying of several points left doubtful in the above investigation. In particular, the number of components observed is not in excess of the number predicted by theory. In the HD spectrum a number of interesting departures from the usual quadratic Stark effect have been observed.

* To be called for after paper No. 160.
[1] Phys. Rev. **47**, 261 (1935).
[2] Proc. Phys.-Math. Soc. Jap. **18**, 469 (1936).